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Astronomy®

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ETX-90EC — $595
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Now you can buy the revolutionary Meade ETX® — the largest selling modern telescope in the world — in either of two apertures, 3.5" or 5". Both models include the very latest in microprocessor-controlled capability.

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#497 Autostar Computer Controller (90, 125)	$149
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#881 Equatorial Table Tripod (125)	59.95
#883 Deluxe Field Tripod (90, 125)	199.95
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#774 Hard Carry Case (90)	99.95
#775 Hard Carry Case (125)	149.95
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#64 Photo Adapter (90, 125)	34.95
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Add the Meade Autostar™ computer to your ETX-90EC or ETX-125EC for automatic GO TO object location …only *$149!*

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RA = 08:04.6
Dec = +36°38
MEADE
ENTER
MODE
GO TO
1
2
3
4
5
6
7
8
9
0
?

Plug the #497 Autostar Computer Controller into your ETX-90EC or ETX-125EC and you're ready for an incredible array of LX200-type capabilities:

Automatic dual-axis GO TO function at 5°/sec to any of more than 14,000 database objects, including deep-space objects (galaxies, diffuse nebulae, planetary nebulae, star clusters — the best objects from the IC, NGC and Caldwell catalogs, as well as all 110 Messier objects); 900 stars (double stars, variable stars, SAO stars); the 8 major planets from Mercury to Pluto; 26 of the brightest asteroids; 15 periodic comets; 50 earth-orbiting satellites; plus user-defined objects and the centroids of all 88 constellations. Select any of these objects, press ***GO TO*** and the telescope automatically slews to the object, placing it in the telescopic field.

Automatic GO TO function to *any* object of known R.A. and Dec.

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The Meade #497 Autostar Computer Controller *(shown actual size)* plugs in to the control panel of the Meade ETX-90EC or ETX-125EC telescope and permits LX200-type automatic object location from a 14,000-object database, a database that includes virtually every astronomical object visible with the ETX-90EC or ETX-125EC — **$149.**

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(right) **Meade ETX-90EC,** shown with optional #497 Autostar Computer Controller plugged into the telescope's control panel.

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Patents pending on ETX-90EC, ETX-125EC, and Autostar.

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COVER ILLUSTRATION: David Seal, Jet Propulsion Laboratory

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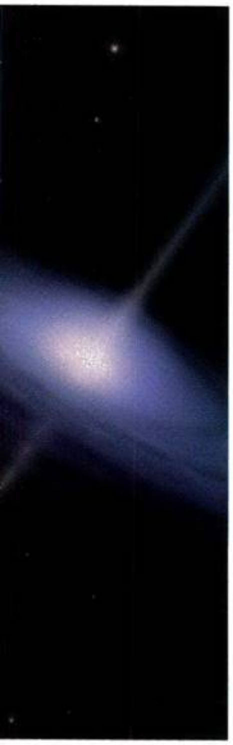

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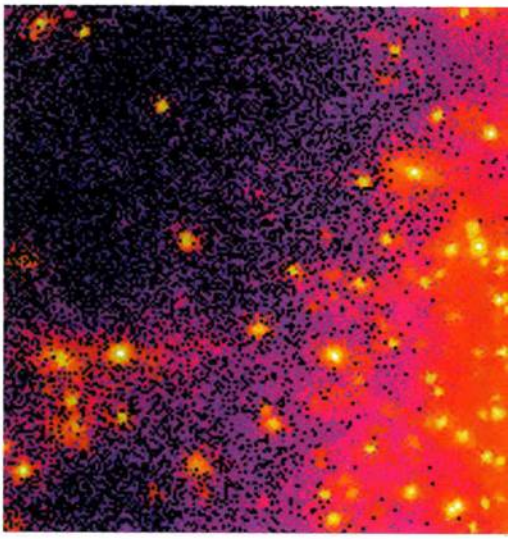

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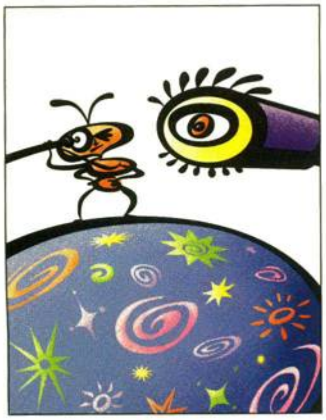

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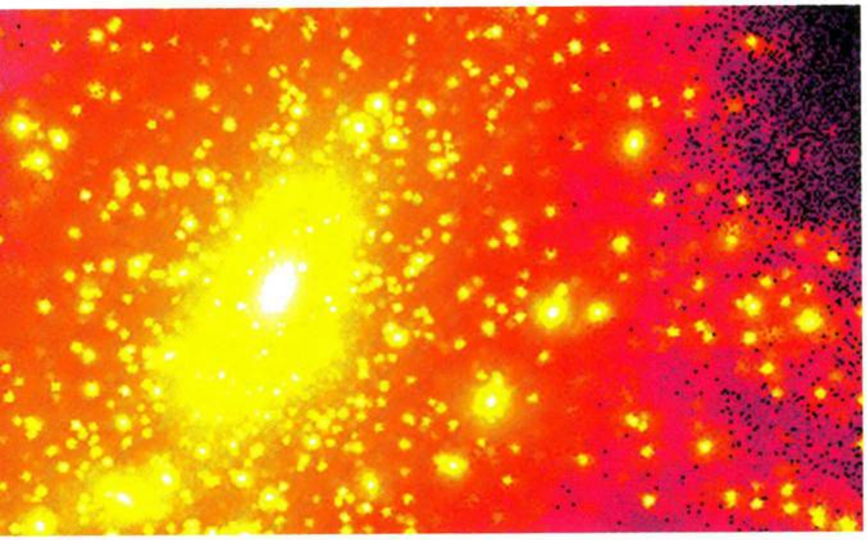

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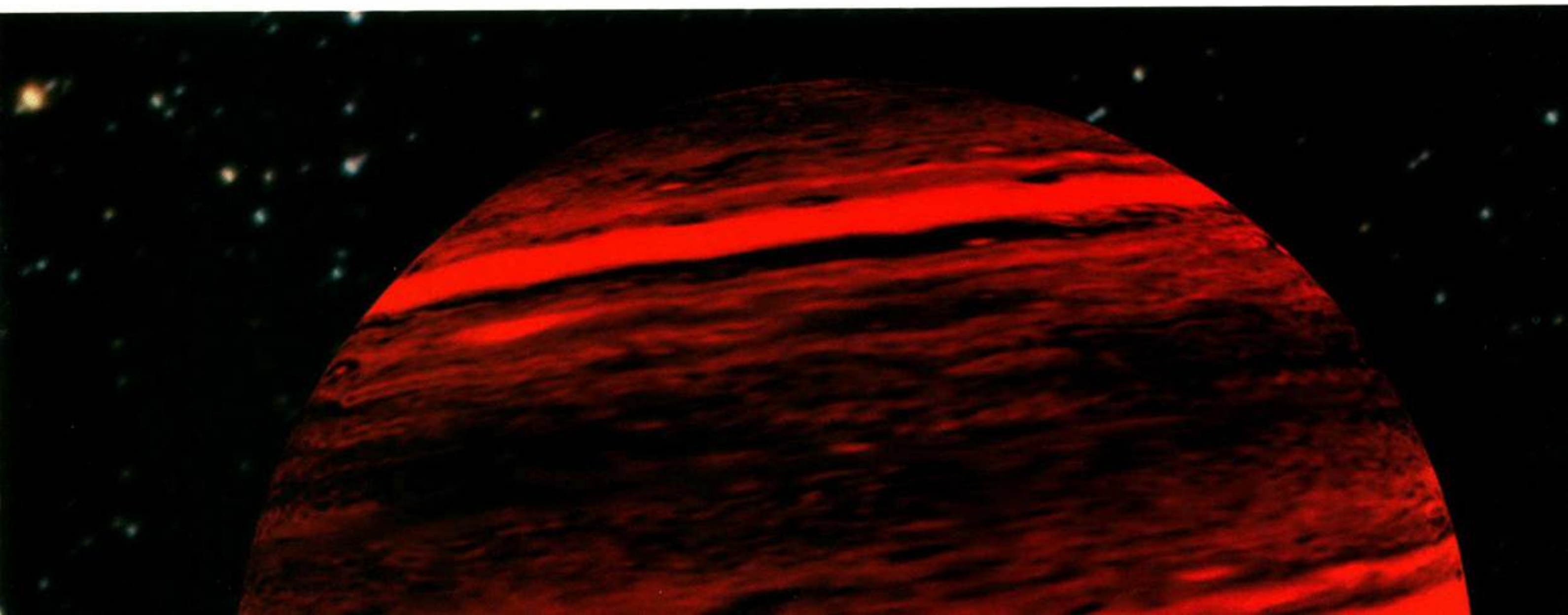

BEHIND THE SCENES

BY BONNIE BILYEU GORDON

Darkening Skies

This month's total eclipse stands to capture more attention than any in the history of the world. It spends a long time casting a shadow on solid ground in lieu of water, unusual because two-thirds of our planet is wet at the surface. What's more, it moves directly over Europe, one of the most densely populated regions of Earth, and continues through the Middle East and across India. The eclipse will darken the skies over millions of people, and most of them will be expecting it, even chasing it.

Aside from the people who live under the path of the shadow, perhaps a million more will pour in from other parts of the world. Millions will be spent on getting there. (And millions of prayers will go up for good weather.) In England, the government has amassed special forces to try to keep things orderly as folks from London (not to mention foreign tourists) try to crowd into the narrow strip of land that ends in Penzance, the only site in the United Kingdom that will offer viewers a total eclipse. If you're going to chase this eclipse, you might look for empty space in Turkey or India. U.S. citizens probably will be steering clear of the very best good-weather sites on eclipse day — in Iraq and Iran. Wherever you go, be polite and careful. Don't forget solar viewers, and don't forget to look carefully around you at other life-forms.

Fred Espenak

If you're near trees, notice how birds come home to roost as the sky darkens. If you are near a farm, you also may see cows returning to their barns. Horses will lie down, as they did in Venezuela in 1998 and in Mexico in 1991. I will be aboard ship again, as I was for the eclipse a year ago, and though I will enjoy the eclipse chase on water and my heart will surely race as the sky darkens, I envy those who will be landlocked and able to see how eclipses tease animals who haven't heard of their coming. Solid ground will also hold an advantage for photographers and telescope users (though we have offered you some help with shipboard use of cameras and telescopes on page 87).

The tours and organized trips have sold out everywhere, but even now it's possible to catch a flight to Ankara or Delhi. And I promise *Astronomy* magazine will run the first decent photo that arrives at my office with the image of the eclipse above a temple-laden landscape.

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Choose either the Meade 203SC/300, with the exact same optical tube assembly as more expensive Meade 8" Schmidt-Cassegrains, or the Model 102ACHR/300 with its exquisite 4" Meade air-spaced achromatic lens. Both telescopes are equipped with the high-performance Meade LXD 300 equatorial mount with dual-axis aluminum worm gears.

SPECIFICATIONS: Models 203SC/300 and 102ACHR/300 — Each telescope includes 8" f/10 Schmidt-Cassegrain *or* 4" f/9 Achromatic Refractor optical tube assembly with EMC super multi-coatings; LXD 300 equatorial mount with aluminum worm gears, micrometric manual slow-motion controls, and setting circles on both axes; manual control for azimuth alignment; elevation control and scale for polar alignment at latitudes from 15° to 50°; adjustable full-length aluminum tripod with bubble level and accessory shelf; 6 x 30mm achromatic viewfinder; eyepiece-holder (1.25"); #918A diagonal prism (1.25"); Series 4000 Super Plössl 26mm eyepiece (203SC) *or* Series 3000 Plössl 25mm eyepiece (102ACHR); provision for addition of optional #812 Polar Alignment Finder; operating instructions. **8" — $795** (+ $65 P & S); **4" — $595** (+ $55 P & S); **#535 R.A. Motor Drive System**...**$99; #812 Polar Alignment Finder**...**$49.**

LXD 500 **For even broader capability, use the Meade® high-precision LXD 500 equatorial mounting, 20% larger and with dual-axis bronze worm gears — the finest equatorial mounting available in its price class.**

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- **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below).*
- **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.
- **Massive LX200-type Fork Mounts:** Manufactured of the same aluminum castings as Meade LX200 models. Massive, rigid mounts that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications.

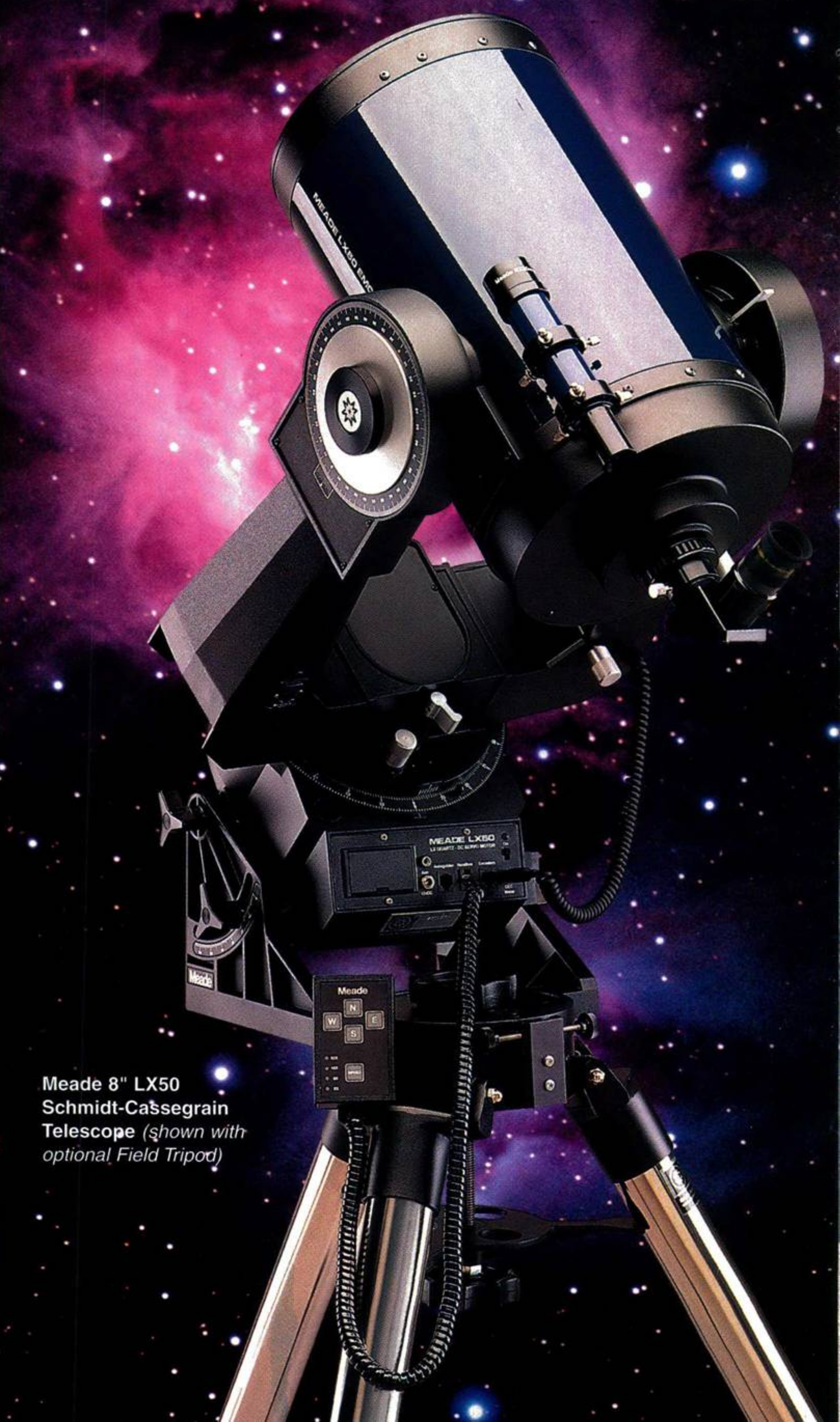
SPECIFICATIONS: 7", 8", and 10" LX50's — Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; Series 4000 Super Plössl 26mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

8" LX50 Schmidt-Cassegrain	**$1395.**
10" LX50 Schmidt-Cassegrain	**1695.**
7" LX50 Maksutov-Cassegrain	**1795.**
Variable-Height Field Tripod	**295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), concealed in special LX50 encoder compartments. ■ Large 32-character, red-backlighted display. ■ Quick 2-star alignment. ■ Four-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(shown above)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$495.** + $15 packing and shipping in the 48 states.



Meade 8" LX50 Schmidt-Cassegrain Telescope *(shown with optional Field Tripod)*

MEADE LX200

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Meade 10" LX200
Schmidt-Cassegrain
Telescope

Prices shown are suggested U.S. national mail-order retail prices.

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In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models *combined*. *Standard-equipment includes:*

- **Superb Optics:** LX200 diffraction-limited imaging capabilities are a legend in the industry; optical performance approaches that of a fine *ED* apochromatic lens.
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- **LX200 High-Precision Pointing**™ is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat no other telescope priced under $40,000 can accomplish.*
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- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.
- **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The compact, optional #1812 Electronic DC Adapter allows for field powering directly from an automobile cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's — Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

8" LX200 Schmidt-Cassegrain	**$2795.**
10" LX200 Schmidt-Cassegrain	**3195.**
12" LX200 Schmidt-Cassegrain	**4495.**
7" LX200 Maksutov-Cassegrain	**3295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

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Now with Series 4000 Super Plössl 26mm eyepiece as *standard equipment!* Consider these features:

Series 4000 SP26mm Eyepiece (1.25"): The premium SP26mm ocular permits all Meade Starfinder Dobsonians to perform absolutely to their maximum capabilities. This $80 eyepiece is now **standard-equipment** on all Meade Dobsonians.

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Rigid, Durable, Beautiful Dobsonian Mountings, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the quick location and easy tracking of celestial objects.

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4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: The same strong, spiral-wound Sonotubes™ used on Starfinder Equatorials *(right),* tubes with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! *Meade Starfinder Dobsonians and Equatorials are the largest-selling Newtonian reflectors of their apertures in the world.* Every Starfinder model opens up the skies to an extremely wide range of serious visual observing; all 110 Messier objects, thousands of NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder Equatorials may be used, in addition, for lunar and planetary photography, and even for limited deep-space photography.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$39; 8"—$49; 10"—$69; 12.5"—$79; 16"—$45 packing, shipped truck freight collect.

$270 Dobsonian Deluxe Accessory Package...only $49.95!

Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the standard-equipment focuser, viewfinder, and eyepiece, ***for a total of only $49.95 additional:***

1 - **Meade #77 2" Giant Rack-and-Pinion Focuser,** with machined aluminum eyepiece-holders for both 2" and 1.25" eyepieces; includes drawtube lock and 2.6" focuser travel. *(reg. $59.95)*

1 - **Meade #637 6 x 30mm Achromatic Viewfinder,** with wide 7° field; 2-ring metal bracket. *(reg. $49.95)*

2 - **Meade Series 4000 Super Plössl 9.7mm and 26mm** multi-coated eyepieces — premium-grade eyepieces for high-resolution lunar, planetary, and deep-space observing. *(reg. $79.95 each)*

Purchased separately, the Deluxe Accessory Package sells for $269.80!

Meade Magellan I Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or *any* object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes the following objects:

7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

MEADE
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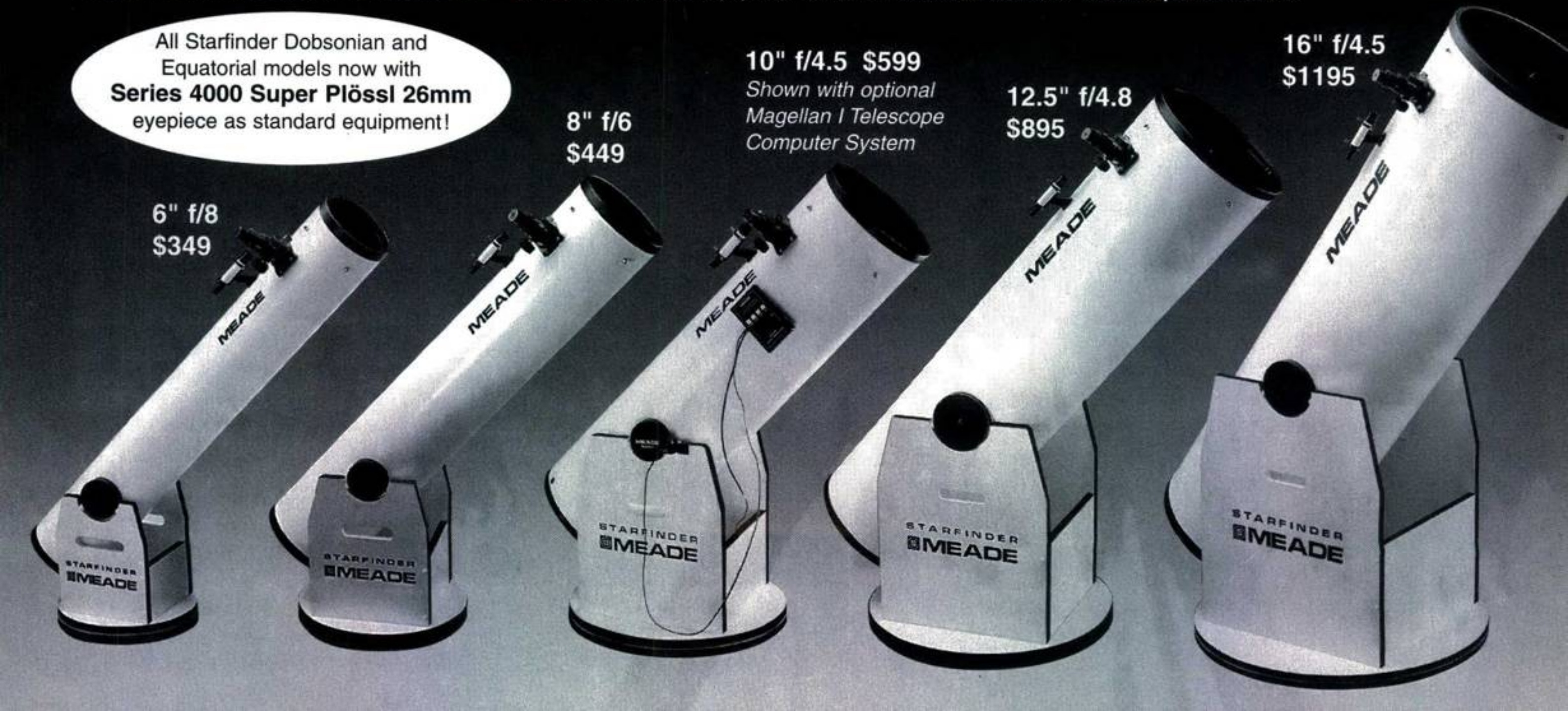
MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I is supplied *complete* with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple.

#2010: for Meade Starfinder Dobsonian
6", 8", 10", 12.5", or 16" . . . . $295.
Packing & shipping in the 48 states—$15.

STARFINDER DOBSONIAN TELESCOPES ***Shown with standard-equipment 5 x 24mm viewfinder and 1.25" rack-and-pinion focuser.***



All Starfinder Dobsonian and Equatorial models now with **Series 4000 Super Plössl 26mm** eyepiece as standard equipment!

6" f/8
$349

8" f/6
$449

10" f/4.5 $599
Shown with optional Magellan I Telescope Computer System

12.5" f/4.8
$895

16" f/4.5
$1195

MEADE
STARFINDER EQUATORIALS

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy a Meade Series 4000 Super Plössl 9.7mm eyepiece ***for only $29.95!*** *Purchased separately, the SP9.7mm eyepiece sells for $79.95.*

New 120-page 1999-2000 Meade General Catalog!

Write, call, or fax Meade Instruments for your free copy.

With DC-powered drive systems for automatic tracking and Series 4000 Super Plössl 26mm eyepiece.

Professional-Grade Optical System: Hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Accessories and Components: Premium-grade multi-coated SP26mm eyepiece (1.25"); #637 6 x 30mm viewfinder with wide 7° field; strong, durable, spiral-wound optical tube with attractive white finish.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System! For fully automatic tracking of celestial objects. Operates over 50 hours from 6 (user-supplied) AA-batteries. Control panel also permits powering the telescope from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 2" giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 2" and 1.25" eyepieces.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 2" giant focuser.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90; 16"—$55 packing, shipped truck freight collect.

Meade Magellan Telescope Computer Systems

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TELESCOPE COMPUTER SYSTEM

Magellan I: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page).*

#2011: for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10" . . . . $295.
#2012: for Meade (DC-powered) Starfinder Equatorial 16" . . . . 295.

MEADE
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Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

#2018: for (DC-powered) Starfinder Equatorial 6", 8", 10" . . 495.
#2019: for (DC-powered) Starfinder Equatorial 16" . . . . 595.

Packing & shipping in the 48 states: Magellan I–$15, Magellan II–$20.

To Order: Contact your authorized Meade Advanced Products Mail-Order Dealer, below. Prices shown are suggested U.S.A. mail-order retail prices.

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 925-447-9570.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

POCONO MOUNTAIN OPTICS, Moscow, PA.
Orders: 800-569-4323; Info.: 717-842-1500.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

ADVANCED PRODUCTS DIVISION
Meade Instruments Corporation
The largest-selling telescopes in the world. ☐ *A NASDAQ company.*
6001 Oak Canyon, Irvine, California 92620 ☐ (949) 451-1450
FAX: (949) 451-1460 ☐ *www.meade.com*

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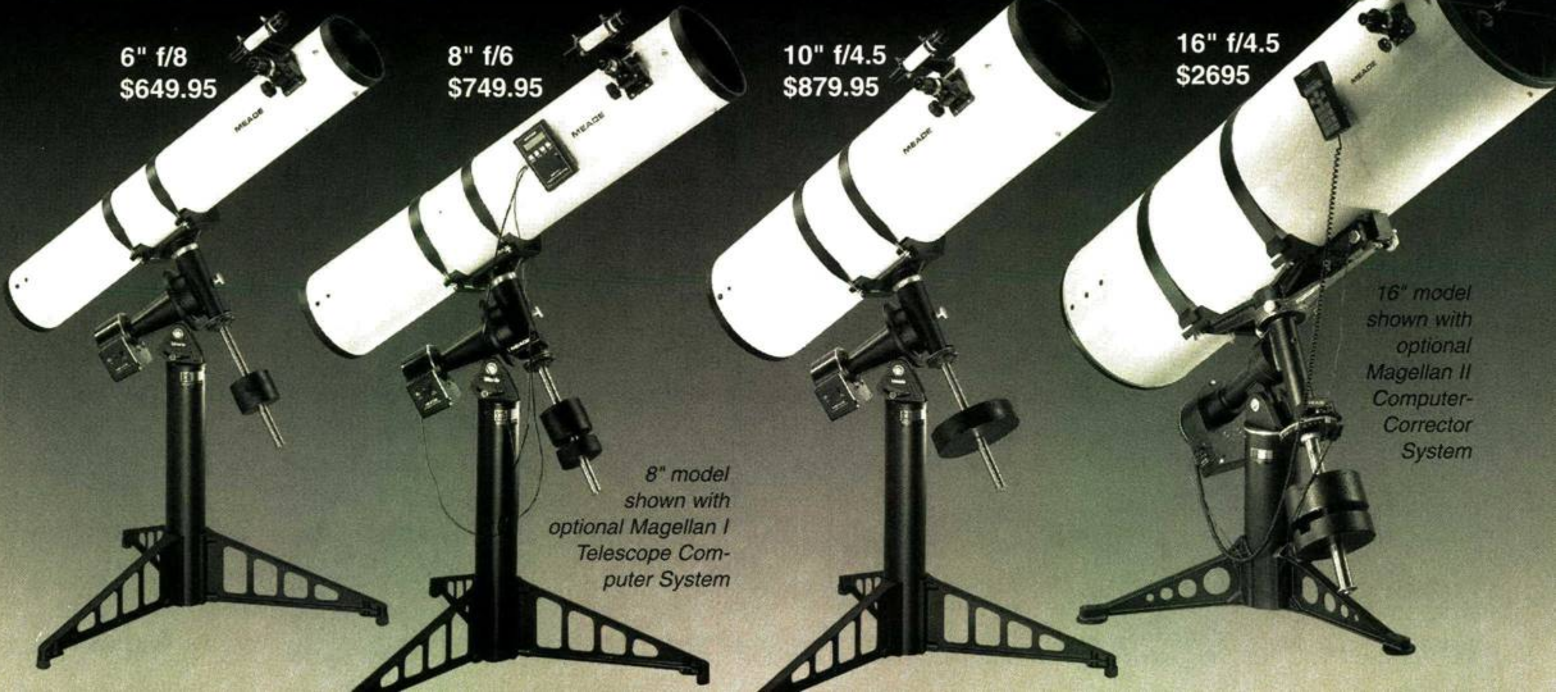
STARFINDER EQUATORIAL TELESCOPES ***Shown with standard-equipment 6 x 30mm or 8 x 50mm viewfinder and 2" giant focuser.***



8" model shown with optional Magellan I Telescope Computer System

16" model shown with optional Magellan II Computer-Corrector System

RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössls 52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (4.54)
32mm (52°); **40mm** (44°)	each:	**99.95** (5.26)
56mm (52°; 2")		**199.95** (7.02)

Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

f/6.3 FOCAL REDUCER/FIELD

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (5.26)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25" **$47.95** (4.54)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (4.54)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (4.54)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

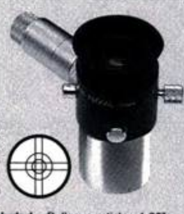
#929 or **#930,** each: **$99.95** (6.85)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.86)

World's Most Advanced Illuminated Reticle Eyepiece



Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (5.26)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (4.54)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (4.54)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (5.26)

Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.

#1206 Electric Focuser: Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. **$149.95** (7.48)

#1205 Electric Focuser: For all other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery.

$169.95 (7.88)

#777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.

$79.95 (6.85)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (5.26)

Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

Series 3000™ Plössls 50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm *(far right in photo)*, an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.86); **40mm** (44° field): **$79.95** (3.86)

#911B
#910B
#908B
#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

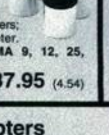
#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (4.54)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (5.26)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (5.26)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (4.54)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (5.26)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (5.26)

#911X
#910X
#908X

Series 4000 Oxygen-III Filters Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade *60-layer* interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

#908X–Threads into 1.25" eyepieces, 26mm dia.	**99.95** (4.54)
#910X–Threads into 2" eyepieces, 44mm dia.	**159.95** (5.26)
#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**149.95** (5.26)

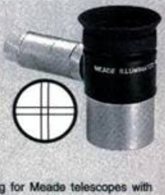
Modified Achromatic Eyepieces



Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (4.54)

MA12mm Illuminated Reticle Eyepiece



Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included.**

$99.95 (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (5.26)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

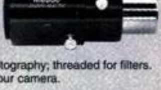
.965": $27.95; **1.25": $29.95** (3.86)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (3.86)

Variable-Projection Camera Adapter (1.25")



Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (3.86)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (3.86)

CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with ***any*** brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexture between the CCD and telescope." — Jack Newton

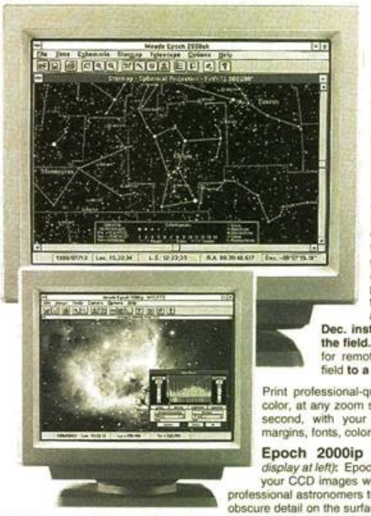
#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XT or ST-7, or smaller; or visual observing with 1.25" eyepieces. **$149.95** (7.02)

#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XT, as well as ST-4 through ST-8; or for visual applications with 1.25" or 2" eyepieces. **249.95** (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) **15.00** (3.86)

#644

#647
MEADE
FLIP-MIRROR SYSTEM



Epoch 2000® Sky Software

The most powerful astronomical software ever made available can now be yours for only $149!

Epoch 2000sk *(upper display at left)*: Now you can use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** With star positions displayed as precisely as **0.01 arc second,** the Trapezium in Orion is no longer shown as a single point, as in other software, **but as four precisely oriented starpoints, just as they appear in the telescope.** No longer do you need to guess the R.A. and Dec. of an object located away from the field center, as in other programs: Epoch 2000sk dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely!

Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

Epoch 2000ip Image Processing Software *(lower display at left)*: Epoch 2000ip makes it easy to enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet. This powerful software includes virtually every technique available for image enhancement. Techniques that bring out detail totally invisible in your original image, transforming it from the ordinary to the spectacular.

EPOCH 2000sk Sky Software: 281,000 objects supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 . . . . **$149**

EPOCH 2000sk-CD Sky Software: 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM **179**

LX200 Interface Cable: for Meade LX200 operation by Epoch 2000sk **25**

EPOCH 2000ip Image Processing Software: Supplied on 3.5" discs for Windows 3.1 or higher; fully compatible with Windows 95 . . . . **$199**

f/3.3 CCD FOCAL REDUCER

Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

NEW!

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture. **$149.95** (5.26)

Plössl 25mm Illuminated Reticle CCD Framing Ocular

NEW!
MEADE
PLÖSSL
CCD FRAMING

Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models and ST-4 through ST-8. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror *(above).* Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25". **$129.95** (4.54)

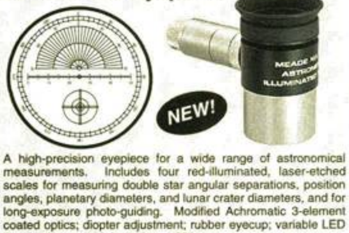
#825 8 x 25mm Right-Angle Viewfinder for ETX-90

Permits comfortable right-angle viewing. Replaces standard-equipment finder on 90mm ETX models, using the same bracket. Wide-angle, achromatic, coated optics; actual field 7.5°. Precise helicoid focusing. **$49.95** (4.26)

#64 T-Adapter for ETX®

Threads to the photo port of all ETX-90 and ETX-125 models. Rigidly couples any 35mm camera with removable lens to the telescope for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera. **$34.95** (3.86)

MA12mm Illuminated Reticle Astrometric Eyepiece



A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photo-guiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyecup; variable LED illumination control; batteries. 1.25". **$119.95** (4.26)

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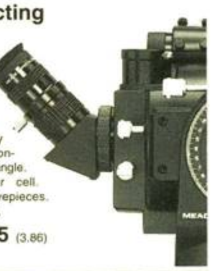

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#520 Electronic Relay: Use with Pictor 201XT on telescopes without autoguider connector or with retrofitted drive corrector. **95.** (5.28)

#541 AC Adapter: For 201XT operation from 115v.AC; includes 25 ft. cord. **35.** (6.56)

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#1247 Electric Focuser for ETX-125 models: **$119.95** (6.85)

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Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes. Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in ( ) next to each price. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

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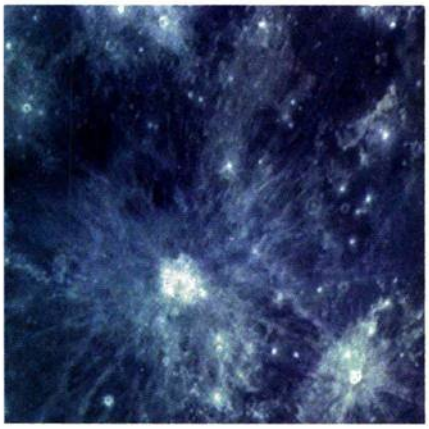
Moon Worshiping

Thanks for the fine Jim Bell article on "Exploring Crater Rays" in the May issue. Lunar rays are fascinating features. So fascinating, in fact, that the Association of Lunar and Planetary Observers, the British Astronomical Association, and the American Lunar Society have begun a joint project to catalog, map, and study them in detail.

If any of your readers would like to participate in the project they may contact me at one of the addresses below. We are encouraging and welcoming sketches, photographs, and electronic images by observers at all skill and experience levels. — *Bill Dembowski, ALPO Coordinator, Lunar Topographical Studies, 219 Old Bedford Pike, Windber, Pennsylvania 15963; Dembow@twd.net*



Help study crater rays in more detail by contributing observations to a joint project sponsored in part by The Association of Lunar and Planetary Observers. Park McGraw

Those Elusive Neutrinos

If neutrinos are so elusive and difficult to detect, how do physicists know that they are counting fewer than expected? How do physicists know what fraction of the available neutrinos their equipment can detect? Also, how accurate are the models for predicting the solar neutrino flux reaching Earth? — *John Wojtowicz, Goodyear, Arizona*

The question is an excellent one. It is really three questions and requires three answers.

The scientists who run solar neutrino experiments test their detectors to make sure they can accurately count the end products of neutrino interactions. The most direct tests are performed on gallium detectors that are exposed to strong artificial sources of neutrinos. The rate of detected neutrinos agrees with the predicted rate.

The shortfalls in solar neutrino rates are determined by comparing observed detection rates with theoretical detection rates. The theoretical rates are calculated by using a model of solar neutrino production and the efficiency at which detectors catch neutrinos. The efficiency is based on a standard physics theory verified in other experiments.

The uncertainties in the predicted neutrino abundances at Earth range from 1 percent for the most abundant and best-known neutrino source to about 20 percent for the rarest and poorest understood neutrino source. The solar neutrino model agrees very well with measurements of the speed of sound throughout the sun. The solar temperature in its interior determines both the predicted abundance of neutrinos and the measured sound speed. The fact that the observed sound speed agrees with the predicted sound speed gives us confidence in our solar model. — John Bahcall, Institute of Advanced Study, Princeton, New Jersey

Our Message to ET

I was shocked to see the use of such an explicit diagrammatic representation of male and female human bodies in your May news story, "Message in a Bottle." What will the aliens think?

Seriously, I am an expatriate living and working in Saudi Arabia and am often appalled and/or entertained by what the censors here manage to find distasteful. I wonder who they're trying to protect and from what. The diagram I speak of was blotted out with black marker, but application of a little suntan lotion revealed the nasty truth beneath. I also wonder who the censors think they're fooling. There's little hope that any moral group, no matter how strong, can completely stifle the growth of a culture into modern times. — *Roy A. Neyman, Saudi Arabia*

The radio transmission into our galaxy to advertise our civilization is the most irresponsible idea I've ever heard. . . . Life out there is just the same as here — crime, war, persecution, and greed. Pirates, interstellar criminals, and warlike alien civilizations can now hone in on us. . . . All this frankly naive experiment has done is to make us a target for the bad guys. You may have destroyed our world — you silly scientists. — *David Williams, Keyhaven, England*

And Now, a New Name for Pluto

Pluto should be renamed "Pluton," ninth particle of the solar system. — *Jon Alexandr, Mill Valley, California*

An English Invitation

We, the members of the Wiltshire Astronomical Society, and surrounding societies, would like to offer *Astronomy* readers an invitation to visit us in the evenings around the day of the eclipse. The week brings a lot of meteor activity so there will be plenty to see.

Whilst we are not in the far reaches of Cornwall, we are ideally situated midway between Avebury Circle, Stonehenge, and the Herschel Museum in Bath, which I read is on the tour agenda for some of you. Our regular viewing site is in the much filmed Georgian village of Lacock (period dramas being so popular theses days), also the site of Lacock Abbey where Henry Fox Talbot developed (literally)

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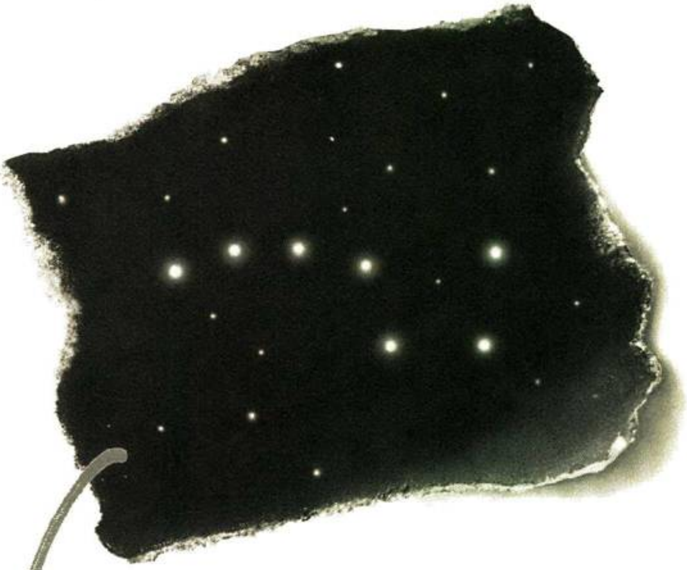
Do you think of this as the Big Dipper?



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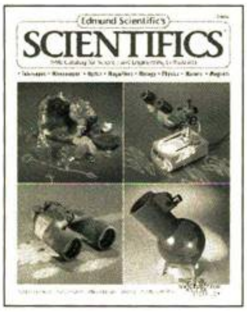

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the negative image photography. It is about 8 miles south of the M4 motorway, midway between Chippenham and Melksham. Because this is a National Trust village there are very few street lights, so our dark site is situated outside a fifteenth-century coaching inn, the Red Lion. Even if it's cloudy, the inn offers a good, relaxing refreshment; we frequently see twice as many stars after imbibing the local ale!

If you are an individual or a coach party please e-mail me and we will arrange viewing evenings to suit. Maps can also be provided. — *Andy Burns, Wiltshire, England; 100616.40@compuserve.com*

SETI Funding

Although I thoroughly enjoyed the insights provided by the selected planetary scientists in "Planetary Oracles" in the March 1999 issue, I disagree on the subject that reductions in research funding for SETI are purely the fault of the U.S. Congress. Some of us commoners actually share the same view.

While most would agree with Alan Stern's comment that the public excitement over possible contact would fade quickly, there are still millions that would experience a lifetime of awe that any intelligent species would attempt any contact with Earth — especially after viewing our travel brochure.

After 60 (light) years of broadcasting television signals into space that clearly depict everything from Wild West shoot-outs and high-tech weaponry to mercury-laden terminators torching the planet, can we imagine what rational extraterrestrial might risk the unknown consequences of speaking up and revealing their precise location to us?

Whether it be breaking through the ice on Europa or drilling an aquifer on Mars, the SETI funding could be put to better use right here in our own solar backyard. — *Dan Olender, Antioch, California*

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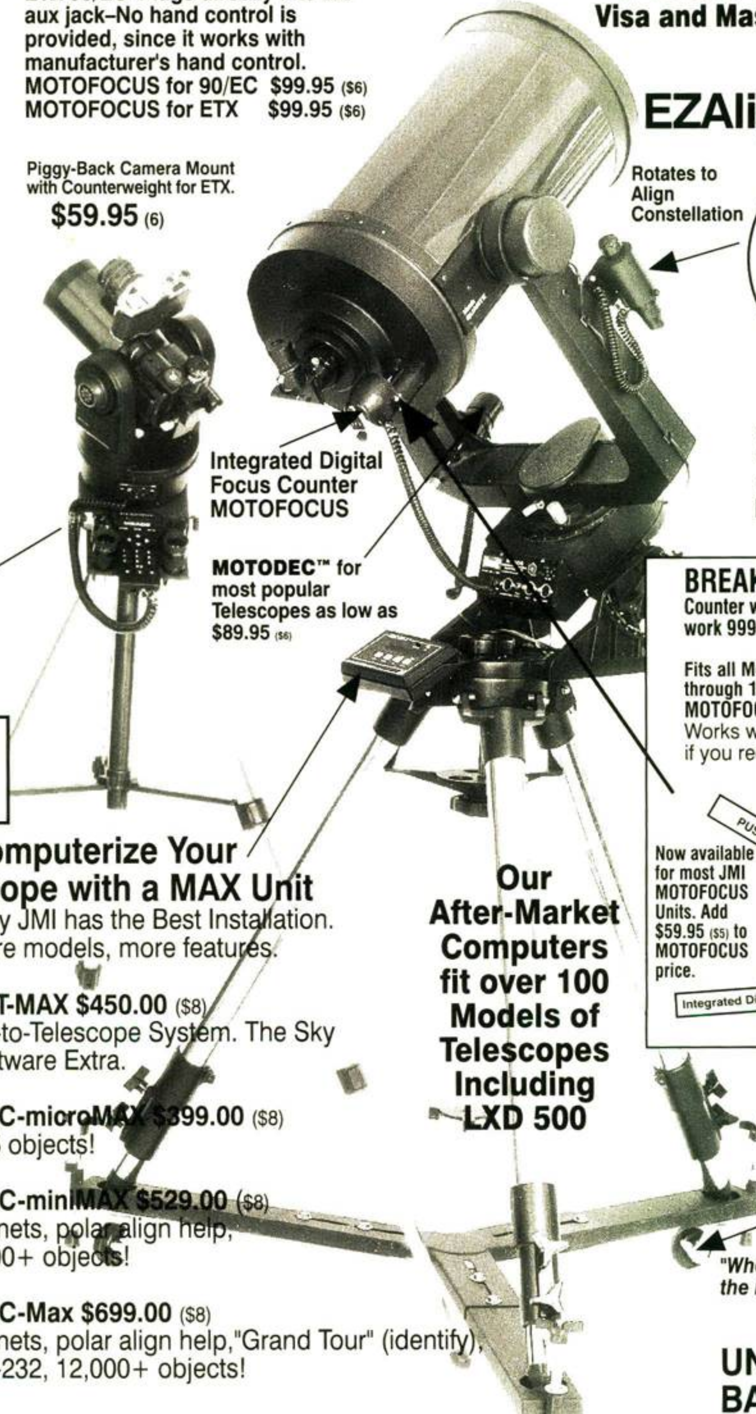
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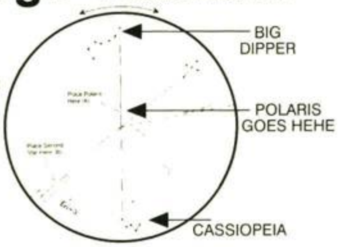
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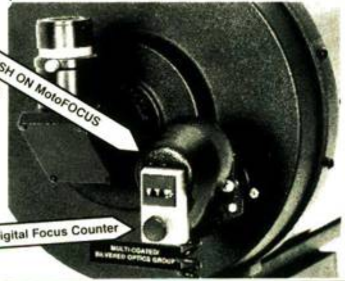
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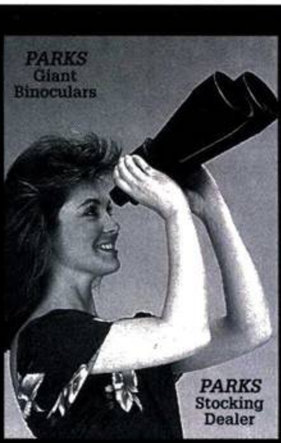
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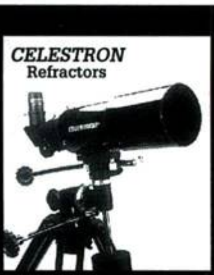
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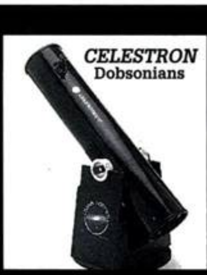
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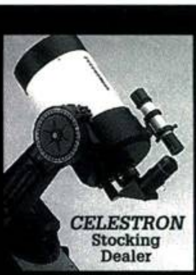
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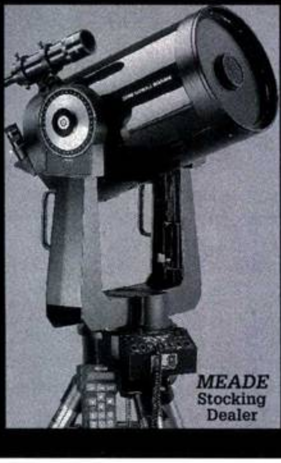
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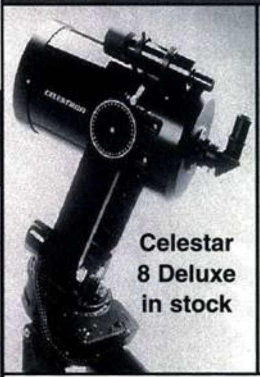
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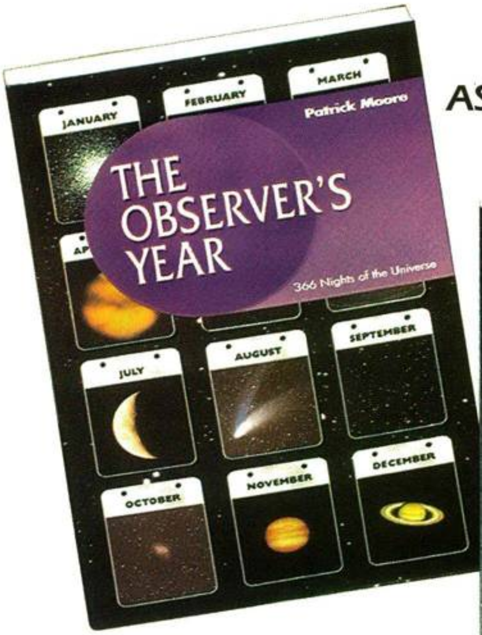
JANUARY
FEBRUARY
MARCH
Patrick Moore
THE OBSERVER'S YEAR
366 Nights of the Universe
JULY
AUGUST
SEPTEMBER
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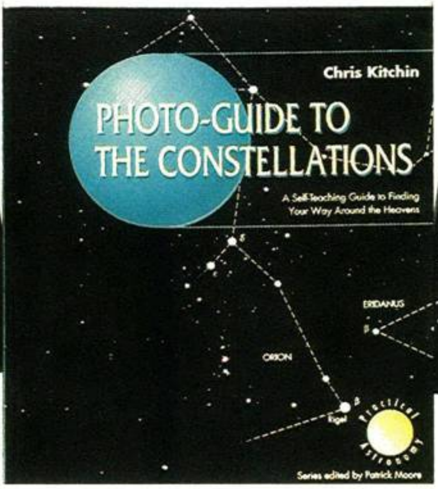
NOVEMBER
DECEMBER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A Self-Teaching Guide to Finding Your Way Around the Heavens
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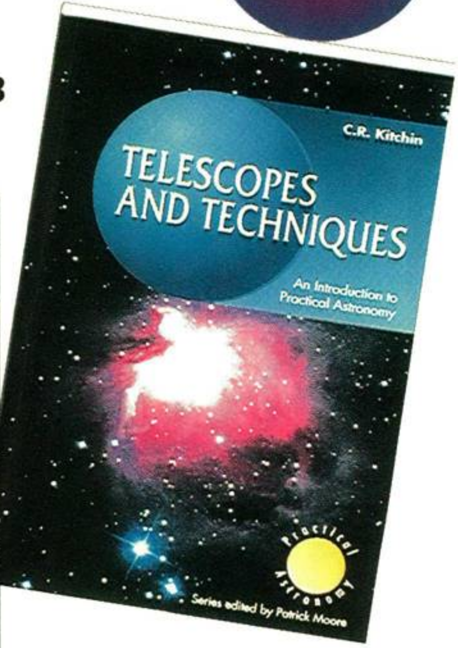
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TELESCOPES AND TECHNIQUES
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An Introduction to Practical Astronomy

by Chris Kitchin

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- All the basics—from buying the right telescope for your needs to identifying star positions and motions
- Observational tips and techniques
- Technical terms like sidereal and solar time, right ascension and declination, and more

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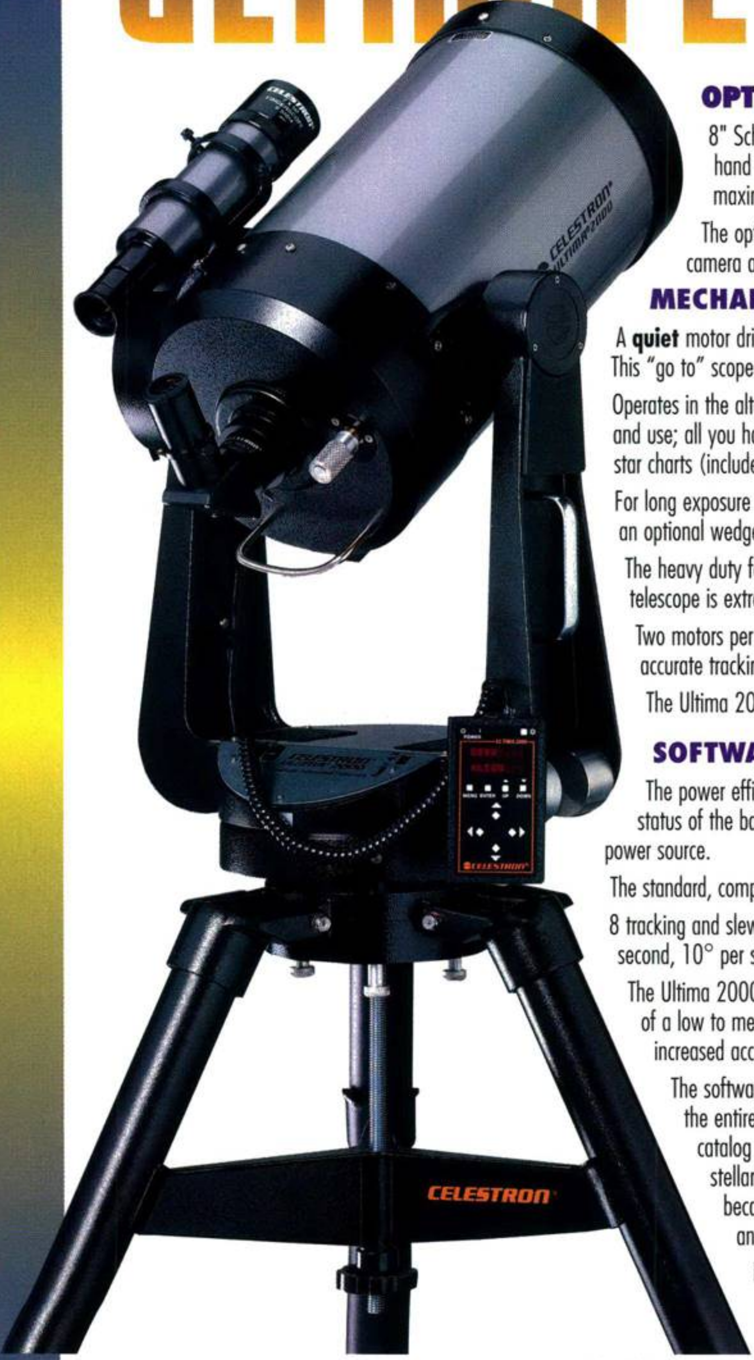
THE UNIVERSE IS JUST A CLICK AWAY WITH THE ULTIMA 2000

Combining state-of-the-art computer technology with a very stable fork mount and superb Celestron optics makes exploring our Universe fun, easy and exciting.



OPTICS

8" Schmidt-Cassegrain Telescope, 2032mm Focal Length, f/10. Each optical system is individually hand figured and guaranteed to be diffraction limited. Multi-coated Starbright® coatings group for maximum light transmission and bright, high contrast images.

The optics are Fastar compatible which provides the potential for CCD imaging using the PixCel CCD camera at an incredible f/1.95! Deep sky images in 30 seconds or less.

MECHANICAL FEATURES

A **quiet** motor driven "go to" computerized telescope built entirely at the Celestron factory in Torrance, California. This "go to" scope won't disturb your neighbors.

Operates in the altazimuth configuration allowing you to find most objects in seconds. Simple to set up and use; all you have to do is find two alignment stars which are easily located on the laminated monthly star charts (included).

For long exposure astrophotography or CCD imaging, use the telescope in the equatorial configuration by adding an optional wedge.

The heavy duty fork mount is extremely rigid and sits on top of a sturdy, adjustable metal tripod. Yet, the telescope is extremely portable and convenient to take with you.

Two motors per axis are standard as well as precision worm gears in both axes that provide very smooth, accurate tracking ability.

The Ultima 2000 can be moved manually (by hand) without losing its star alignment.

SOFTWARE/ELECTRONICS FEATURES

The power efficient DC telescope is operated with the included AA batteries. A built-in voltmeter monitors the status of the batteries. Optional adapters are available to run the telescope from a car battery or from an AC power source.

The standard, compact hand controller operates the various functions such as position, identify, speed, pointing, etc.

8 tracking and slewing speeds are available – sidereal, solar, lunar, King, 2x sidereal, 0.5x sidereal, 2° per second, 10° per second.

The Ultima 2000 has impressive pointing accuracy where the object selected will always be in the field of view of a low to medium power eyepiece. Includes Enhanced Encoder Resolution and Relative Go To mode for increased accuracy which is ideal for centering objects on a CCD chip.

The software database contains over 10,000 deep-sky objects as well as major planets. The objects include the entire Revised New General Catalog, the Messier catalog, selected objects within the IC catalog and the ESO and Uppsula catalogs, 241 interesting double and multiple stars, and 661 non-stellar objects. The database may not be the largest in the industry but it is one of the most useful because of the object selection. In addition, the display of the object data is the most complete of any commercial computerized telescope.

For beginners and educators, a special Tour mode is available which allows you to view 15 popular objects by season, automatically.

To quickly and easily find your favorite objects, the telescope offers 25 user-defined selections.

The Ultima 2000 can by operated by a computer using popular astronomy software such as *The Sky*. Programs can also be written by the user to control the telescope.

Other standard features and accessories include: 9x50 finderscope, multi-coated 26mm Plössl eyepiece – 1¼" (78x), star diagonal – 1¼", LED display, auto guider port, northern and southern hemisphere operation, comprehensive instruction manual.

For more detailed information on this telescope, contact a Celestron dealer or Celestron.
Visit our Web site at www.celestron.com

CELESTRON® 2835 Columbia Street, Torrance, CA 90503 • (310) 328-9560 • FAX (310) 212-5835

HD TELESCOPES

HEAVY-DUTY TELESCOPES OFFER MORE VALUE THAN YOU MIGHT THINK!

HD SERIES TELESCOPES – two refractors – an 80mm (3.1") with a focal length of 900mm (f/11) and a 102mm (4.0") with a focal length of 1000mm (f/10); two Newtonians – a 114mm (4.5") with a focal length of 900mm (f/8) and a 150mm (6.0") with a focal length of 100mm (f/7).

All models come standard with a 6x30 finderscope and a premium 20mm Plössl 1¼" eyepiece.

OPTICS – all **HD** series telescopes have diffraction limited, premium optics manufactured to Celestron's uncompromising standards. The star images are classic textbook Airy disks. The Newtonians have multicoated optics and the refractors are fully multicoated to provide higher light transmission yielding bright, high contrast images.

The refractors have very good color correction. The 150mm Newtonian uses a state-of-the-art proprietary optical design incorporating an auxiliary correcting lens to reduce various aberrations, flatten the field and allow the tube length to be shortened – and it is superior to most fast parabolas.

MOUNT AND TRIPOD – the **HD** telescopes use the CG-4 German equatorial mount. It is a precision, heavy-duty mount which is upgraded and much better than the older polaris mounts.

The precision worm gears are extremely smooth in motion and the tracking accuracy is excellent. Optional motor drives make astrophotography easy and fun.

The tripod is a sturdy, adjustable height unit made of aluminium and it includes a heavy-duty accessory tray.

In addition, the 102mm refractor is offered with a **HD** altazimuth mount. This mount is easy to use and has slow motion controls (flexible cables) on both axes to allow for quick and easy pointing and tracking.

The superb optics with rigid mount and tripod of the **HD** telescopes allow you to enjoy awesome details of our moon such as craters, rills and mountain ranges; Saturn and its rings; Jupiter with its belts and moons; Mars, Venus and Mercury; deep-sky objects such as galaxies, nebulae, double stars and star clusters.

C114-HD
C102-HD
C150-HD
C102-AZ
C80-HD

For more detailed information on these telescopes, contact a Celestron dealer or Celestron.
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STAR HOPPER® DOBSONIANS

Dobsonian telescopes, by design, combine the strong performance of a Newtonian system, with a simple altazimuth mount. Celestron's Dobsonian design, the Star Hopper,® is great for beginners because it's very easy to use and quite economical, yet has advanced features even an experienced observer will appreciate.

STAR HOPPER 4½

- 4½" (114mm) Aperture - 910mm Focal Length, f/8
- Aluminum Optical Tube
- High Quality, Smooth Dob Mount
- Standard 1¼" Accessories: 25mm SMA Eyepiece (36x) and Focuser
- 5x24 Finderscope
- Collimation Tool Standard
- Weight: 18 lbs.

Celestron's Star Hopper 4½ is unique, small Dobsonian telescope that's great for both your own use and for gift-giving. The mount and telescope tube are shipped fully assembled in one box, ready for you to begin observing immediately.

4½"

8"

STAR HOPPER 6 & 8

- 6" (152mm) - 1220mm Focal Length, f/8
- 8" (203mm) - 1220mm Focal Length, f/6
- Precision annealed Pyrex primary mirrors - better than glass used by some competitors, ensure faster temperature stabilization and the highest quality steady optical figure
- Optics are diffraction limited
- Multicoated Primary Mirrors
- Teflon and Nylon surfaces guarantee smooth performing mechanics
- Unique Balance System
- 25mm SMA Wide Angle Eyepiece - 1¼"
- 5x24 Finderscope
- 1¼" Rack and Pinion Focuser
- Collimation Tool - very useful and unique to Celestron
- Made in the U.S.A
- Weight: 6" @ 39 lbs., 8" @ 55 lbs.

6" and 8" Dobs offer one of the best values for an astronomer. Large primary objectives and affordable prices allow first-time astronomers to explore deep-sky objects with ease.

The Dovetail Balance Bar allows for precise balancing of the tube, making the smoothest possible movement. No need to add counterweights!

In summary, *Astronomy Magazine* says, "Star Hopper® is a milestone on the road toward a better commercial Dobsonian telescope. Star Hopper's innovative mirrors, mirror cell and adjustable altitude bearings, combined with its crisp, sharp images more than meet what every Dobsonian owner hopes to have in an easy to use, backyard telescope."

For more detailed information on these telescopes, contact a Celestron dealer or Celestron.
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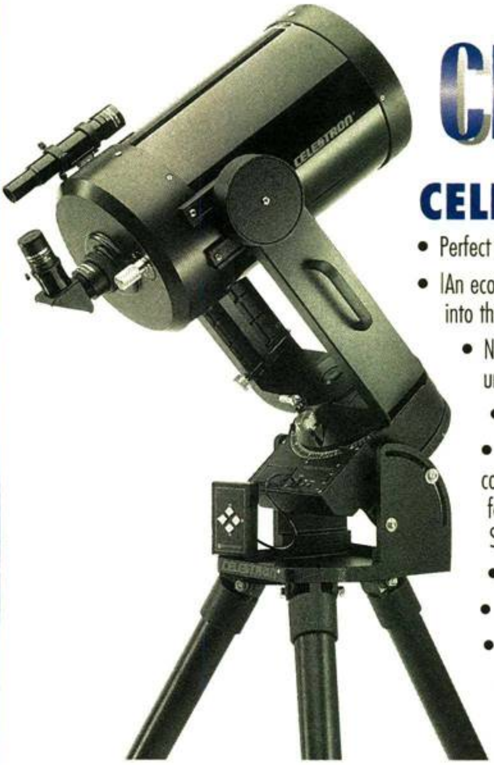
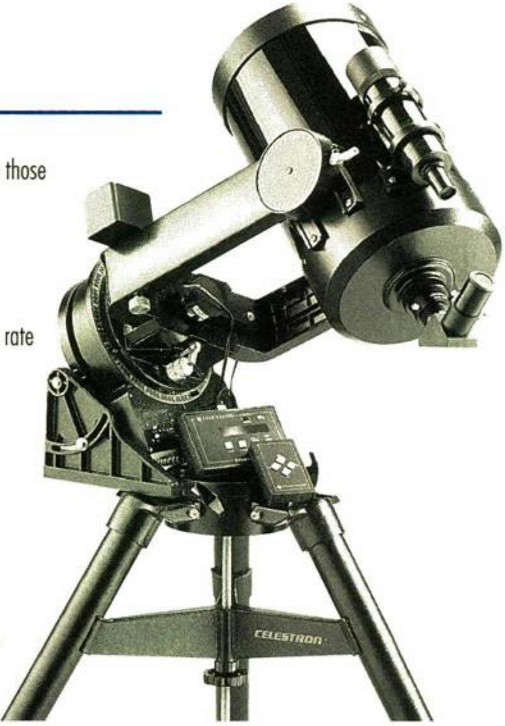


CELESTAR 8 TELESCOPES

CELESTAR 8

- Perfect for a first time astronomer.
- IAn economical but full featured 8" (2032mm f/10) Schmidt-Cassegrain. A considerable amount of engineering work went into the design of the Celestar 8.
- No sacrifice was made in the optics. Celestron's carefully hand-figured system delivers diffraction-limited optics of unsurpassed quality. Starbright® coatings are standard.
- The energy efficient DC electronics are powered by a 9 volt alkaline battery for easy astronomy on the go.
- The totally cordless electronics have a built-in drive corrector which is activated when using the optional hand control. The R.A. motor's main tracking speed is an accurately regulated sidereal rate. The optional hand control allows for fast and slow override of R.A. tracking speed and ± operation of the optional DEC motor. A comment from the Sky & Telescope review – "the digital electronics delivered a near-perfect sidereal tracking rate."
- The Celestar 8 drive can operate in the Northern or Southern hemisphere from 0° to 90.°
- The unique Wedgpod is a combination tripod and wedge which is very stable.
- Made in the U.S.A.
- Standard accessories include: 6x30 Finderscope, Star Diagonal – 1¼" and a 25mm SMA Eyepiece – 1¼" (81x).
- Weight – 41 pounds.

CELESTAR 8 DELUXE



- For the more serious astronomer.
- This telescope utilizes the same superior optics and has all the features of the Celestar 8, but is enhanced, for those who prefer a premium version.
- This model has a heavier duty fork mount and drive base, with a precision worm gear drive system.
- Superior tracking accuracy is attained with this advanced drive system, which has four tracking rates and PEC (Periodic Error Correction).
- For the kind of versatility that makes observing a pleasure, the hand controller makes available a micro guide rate of .5x sidereal and a slew rate of 8x sidereal.
- The stepper motor drive electronics are cordless and operate on two 9 volt batteries.
- The Celestar 8 Deluxe has many features that are necessary for the more serious amateur astronomer, particularly if you're interested in astrophotography or CCD imaging with the PixCel or other CCD cameras.
- Fastar compatible for f/1.95 CCD imaging – deep sky images in 30 seconds or less!
- Made in the U.S.A.
- The standard accessories for this telescope include: Declination Motor, Car Battery Adapter, Hand Controller, Wedge and a Tripod with adjustable height that's exceptionally rigid and sturdy .
- Also standard is a *large* 9x50 Finderscope, Star Diagonal – 1¼" and a multi-coated 26mm Plossl Eyepiece – 1¼" (78X).
- Weight – 52 pounds.

ADVANCED ASTRO MASTER®

CELESTRON
Advanced Astro Master

The Celestar 8 Computerized and the Celestar 8 Deluxe Computerized telescopes are the same as the Celestar 8 and Celestar 8 Deluxe but with the addition of a factory installed and tested Advanced Astro Master.®

Its pointing system contains a data base of over 10,000 objects. Once aligned, it will guide you to any one of these objects. Included are the entire RNGC catalog, the Messier catalog, IC catalog (selected objects), major planets, over 241 interesting double and multiple stars and a user definable catalog of 25 objects. Operates on a standard 9V battery.

Contains an RS-232 serial interface to enable usage with programs like "The Sky"™ by Software Bisque.

For more detailed information on these telescopes, contact a Celestron dealer or Celestron. **Visit our Web site at www.celestron.com**

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ASTRONEWS

CLOSE ENCOUNTERS

Millions of New Comets Coming

Comet lovers may be heartened, while others will be frightened by recent findings indicating that millions of new comets are destined to head our way from the outer solar system. About 2.4 million comets will be scattered toward Earth and a few could collide with us. However, there is no need to panic: The comets won't arrive for a few million years.

A team of astronomers mapping out the traffic pattern of stars in our solar system's neighborhood discovered the stars' destabilizing effects on the Oort Cloud. Most long-period comets come from the Oort Cloud, a vast, spherical reservoir of comets far beyond the planets. Astronomers estimate that several trillion comets reside in the zone that stretches 1 to 2 light-years from the sun — halfway to the nearest stars. When a star passes near the cloud, the resulting gravitational nudge can launch lots of comets toward the sun.

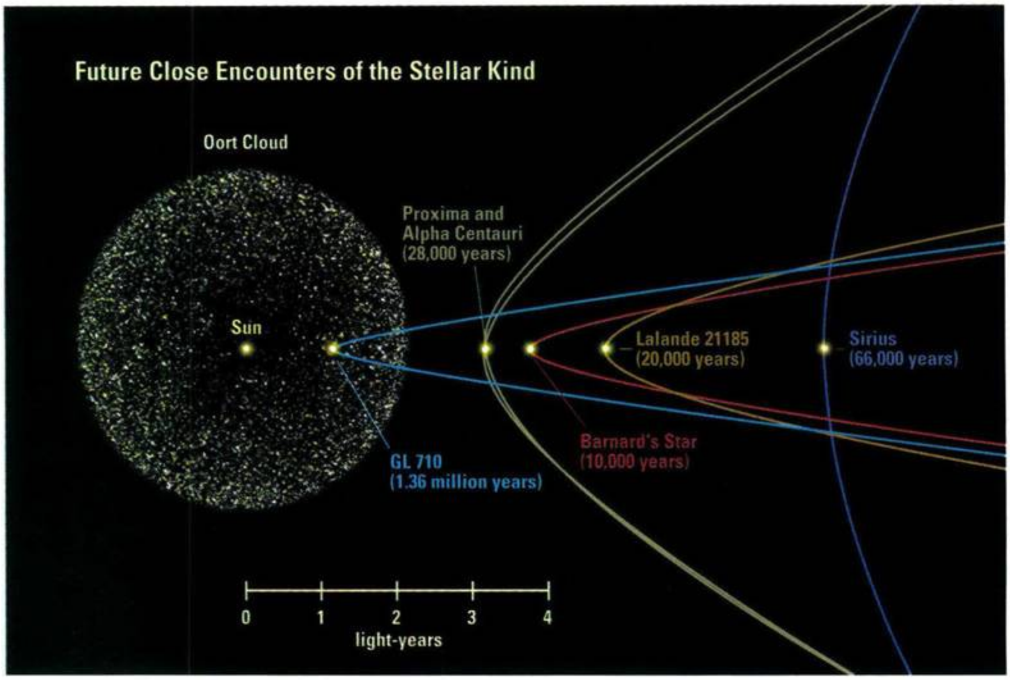
A team led by Joan García-Sánchez of the Jet Propulsion Laboratory in Pasadena, California, combined observations made by the European Hipparcos satellite with those from the ground. The team's goal is to determine which stars move closest to the sun during the past and future 10 million years.

In a paper published in the February issue of *The Astronomical Journal*, the team wrote that Sirius, currently the brightest star in the sky, will come within 7.5 light-years of Earth in 66,000 years. Barnard's Star will come within 3.7 light-years of Earth in just 10,000 years. And Proxima Centauri, our solar system's nearest star, will brush within 3.2 light-years in 27,000 years. While all three come close, none is expected to disturb the Oort Cloud.

However, the effect of GL 710, a currently obscure star, is more worrisome. In just 1.4 million years — brief in astronomical terms — GL 710 will actually dip into the middle of the Oort Cloud as it passes within 1.1 light-years of the sun.

To estimate the effect of the close encounter with GL 710, which is half the sun's mass, the team ran a computer simulation. The conclusion: The star would launch roughly 2.4 million comets on paths that will eventually cross Earth's orbit. The storm will be spread out over about 2 million years, so only about one new long-period comet a year will appear in Earth's traffic pattern. Still, when compared with the current rate of about two comets per year, GL 710 will trigger a 50 percent increase in local cometary traffic.

— Richard Talcott


Future Close Encounters of the Stellar Kind
Oort Cloud
Sun
Proxima and Alpha Centauri (28,000 years)
Lalande 21185 (20,000 years)
Sirius (66,000 years)
Barnard's Star (10,000 years)
GL 710 (1.36 million years)
0
1
2
3
4
light-years

Astronomy: Elisabeth Rowan

In about 1.36 million years, the star GL 710 will penetrate the Oort Cloud and send 2.4 million comets in to Earth-crossing orbits. Other close-approaching stars are expected to have little effect on the Oort Cloud.

The sudden appearance in 1995 of Comet Hale-Bopp was a reminder that the Oort Cloud is a vast reservoir of comets that can come our way at any time.

Marino Fonovich

ACCESSORIES BY CELESTRON

The Celestron Accessories here are universal – use with virtually any telescope.

PLÖSSL EYEPIECES

In a recent *Sky and Telescope* review, Celestron's 1¼" Plössl eyepieces were rated as **top ranking**, and found to outperform many similar, but more expensive eyepieces. An exceptional value! Celestron offers these premium eyepieces at affordable prices, yet they're among the best designed and corrected eyepieces available. They're **multicoated** for enhanced contrast and all models are threaded to accept Celestron colored eyepiece filters. **Focal length with field of view:** 6.3mm (52°), 7.5mm (52°), 10mm (52°), 12.5mm (52°), 17mm (52°), 20mm (52°), 26mm (50°), 32mm (52°), 40mm (46°).

ULTIMA® EYEPIECES

These are Celestron's top of the line 1¼" eyepieces. They feature long eye relief and a wide field, and each air-to-glass surface is **fully multicoated** to enhance contrast levels. These special eyepieces are computer designed to keep visual aberrations to an absolute minimum. Recently, *Sky and Telescope* reviewed Celestron's Ultima® eyepieces and rated them **best in their class**, with greater contrast and image sharpness than the competitive models of other manufacturers. The inside surfaces and edges of all lenses are blackened, to keep out reflected light. Threaded barrels accept Celestron thread-in filters. **Focal length with field of view:** 5mm (50°), 7.5mm (51°), 12.5mm (51°), 18mm (51°), 24mm (51°), 30mm (50°), 35mm (49°), 42mm (36°).

LV EYEPIECES

These Vixen brand 1¼" eyepieces (6 to 8 elements) are a new breed, using the rare earth glass lanthanum in one of their field lenses, for almost total freedom from any visual aberrations. All focal lengths have a comfortable 20mm of eye relief. Even when using the 2.5mm LV eyepiece on a telescope, you'll have eye relief of 20mm! These eyepieces also feature **fully multicoated** lenses for optical excellence. **Focal Length with field of view;** 2.5mm (45°), 4mm (45°), 5mm (45°), 6mm (45°), 9mm (50°), 10mm (50°), 12mm (50°), 15mm (50°), 20mm (50°), 25mm (50°).

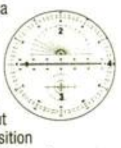
LV ZOOM EYEPIECE

This super premium 1¼" zoom eyepiece has a focal length of 8mm to 24mm. It is the finest zoom eyepiece for low to medium power observing. It's an excellent eyepiece that performs superbly, with **fully multicoated** surfaces. It offers an apparent field of 40° at 24mm and 60° at 8mm. Eye relief ranges from 15mm to 19mm.

CROSS HAIR EYEPIECE

This 1¼" eyepiece is of the Kellner design, with a focal length of 20mm. It's ideal for centering alignment stars when using digital setting circles or computerized telescopes. A useful all-around eyepiece for many applications, including terrestrial observing.

MICRO GUIDE EYEPIECE



This multifunction 1¼" guiding eyepiece features a laser-etched reticle with a built-in battery illuminator. The eyepiece is a **multicoated** 12.5mm Orthoscopic. Usage possibilities include: direct guiding on stars outside the center of the field of view; greatly improved off-axis guiding to capture much fainter, sharply focused guide stars without reducing limiting magnitude; and measuring position angles and separation of double stars. **Its finely etched micrometer scale** has gradations 50 microns apart and 15 microns wide. Included are: the eyepiece, built-in cordless illuminator with adjustable brightness control, batteries and instructions.

BARLOW LENSES

Celestron's premium quality .96" and 1¼" achromatic Barlow lenses are compact and lightweight. Both are under three inches long, with the 1¼" lens weighing in at 4 ounces and the .96" lens a mere 2 ounces! The clear aperture is 27mm on the 1¼" model, and 21mm on the .96" unit. The .96" Barlow is **fully multicoated** and the 1¼" lens is **multicoated**. The Ultima® Series Barlow (2x – 1¼") is an air-spaced, three element apochromatic design with a 27mm clear aperture. This lens features a very high quality, **fully multicoated** design. Amazingly compact and lightweight, it's just 5 ounces and 2¾" in length.

DIAGONALS

Celestron's Erect Image Diagonals are an Amici prism design. This design allows you to look into the telescope at a 45° angle, at images that are oriented properly, meaning the image is upright and correct from left to right. .96" to 1¼" models are available. Use of Celestron's hybrid .96" to 1¼" 45° Erect Image Diagonal on a telescope equipped with .96" eyepieces means greater versatility. This diagonal will allow you to use 1¼" eyepieces to obtain a larger field of view and better eye relief. A 90° 1¼" Erect Image Diagonal is available for those who prefer that angle. A 1¼" Star Diagonal (90°) is also available.

EYEPIECE FILTERS

Eyepiece filters are an invaluable aid in lunar and planetary observing. They reduce glare and light scattering, increase contrast through selective filtration, increase definition and resolution, reduce irradiation and lessen eye fatigue. Celestron's filters are made of high quality, solid plane parallel glass with excellent homogeneity. They're **antireflection coated** to prevent glaring and ghosting. All eyepiece filters are threaded to fit Celestron's, and most other manufacturer's, 1¼" eyepieces, and offer a full 26mm clear aperture. Filters available individually are: #12 Deep Yellow, #21 Orange, #25 Red, #58 Green, #80A Light Blue, #96 – 25% T, #96 – 13% T, Polarizing. In addition four different sets of four filters each are available.

1¼" POLARIZING FILTER SET

It's particularly useful for reducing glare while observing the moon, double stars, the planets and terrestrial subjects. You can vary the degree of transmission. By causing the amount of transmitted light to vary, the filters become, in effect, a continuously variable neutral density filter.

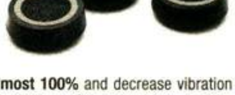
LPR FILTERS

Light Pollution Reduction (LPR) Filters are designed to selectively reduce the transmission of certain wavelengths of light, specifically those produced by artificial light. As a result, Celestron LPR Filters darken the background sky, making deep-sky observation of nebulae, star clusters and galaxies possible from urban areas. While blocking unwanted light, Celestron LPR Filters permit the transmission of more desirable wavelengths. This will improve your viewing of emission nebulae, both from urban and rural settings. They're also protected with a **broadband antireflection coating** to prevent ghosting and to improve contrast. They provide superior performance and contrast over competitive models. A 1¼" model threads into 1¼" eyepieces to work with virtually all telescopes.

MOON FILTERS

Celestron's Moon Filter threads into 1¼" eyepieces and aids in reducing the brightness of the moon and improving contrast, so greater detail can be observed on the lunar surface. The clear aperture is 21mm.

VIBRATION SUPPRESSION PADS



Telescope vibration is caused by windy conditions, an unsteady mount or tripod or even an accidental bump to the instrument, and results in reduced image quality. Celestron's set of three Vibration Suppression Pads **will reduce vibration time by almost 100%** and decrease vibration amplitude. The pads fit between the bottom of the tripod legs and the ground, a simple and functional solution to the problem of image disturbance.

NIGHT VISION FLASHLIGHT

Celestron's premium model for astronomy uses **two red LEDs** to preserve night vision better than red filters or other devices. Brightness is adjustable. Operates on a single 9 volt battery (included).

LENSPEN™

A superb new tool in optical lens cleaning technology. Perfect for cleaning binocular lenses, small aperture spotting scopes and telescopes, eyepieces, and other optical items. The LensPen™ comes with a handy retractable dust removal brush and a special non-liquid cleaning element, designed to never dry out. Safe and very easy to use.

SKY MAPS

Celestron Sky Maps are the ideal teaching guide for learning the night sky. You wouldn't set off on a road trip without a road map, and you don't need to try to navigate the night sky without a map either. Even if you already know your way around the major constellations, these maps can help you locate all kinds of fascinating objects. The front cover has a specially designed **luminous planisphere** that rotates to simulate the seasonal progression of celestial objects through the sky. When the planisphere is pre-exposed to light, star positions glow brightly against a dark background, mimicking actual constellations. More than a thousand stars and deep-sky objects are listed and charted.

PLANISPHERE

A simple and inexpensive tool for all levels of observers, from naked eye viewers to users of highly sophisticated telescopes. The Celestron Planisphere makes it easy to locate stars for observing and is a great planet finder as well. The Celestron Planisphere comes in three different models, to match the latitude from which you're observing: 20° to 40°, 30° to 50°, 40° to 60°.

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TELESCOPE EQUATORIAL MOUNT–CG-4

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BRIGHT STAR

Eta Carinae Unexpectedly Flares Up

▶In a completely unexpected development that is exciting professional and amateur astronomers alike, the powerful blue supergiant Eta Carinae has nearly doubled in brightness in the past 14 months.

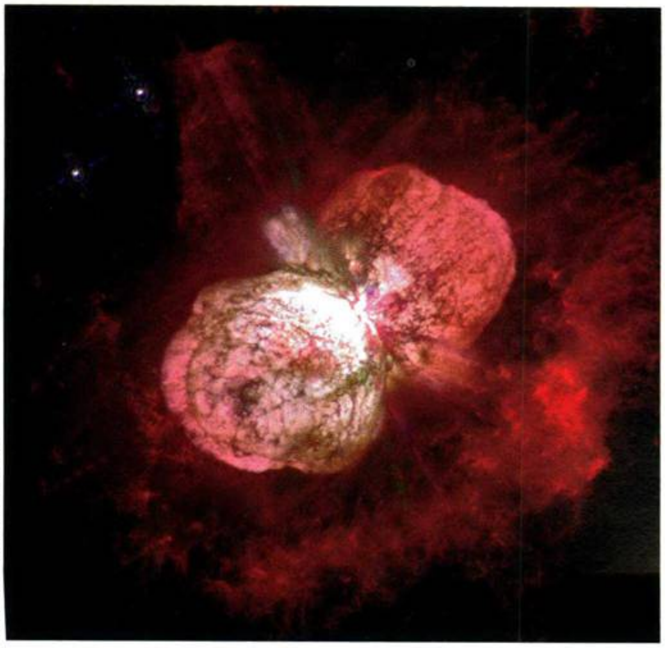
Kris Davidson of the University of Minnesota and Ted Gull of NASA's Goddard Space Flight Center recently discovered the activity while comparing images taken December 1997 by the Hubble Space Telescope (HST) with those taken February 1999 by HST. The star's brightness had jumped 75 percent. Astronomers using ground-based observations in Chile, South Africa, and Australia confirmed the findings of Davidson and Gull.

Eta Carinae is a luminous blue variable (LBV) about 7,500 light-years away. Among the most massive and luminous stars in the universe, LBVs undergo periodic eruptions, each of which throws off the equivalent of several of our suns. HST images show a vast cloud of dust and gas ejected during the star's most recent eruption.

Astronomers in the 1840s observed Eta Carinae's previous eruption, when it brightened to first magnitude. The star's most recent activity could herald either the onset of a new eruption or the thinning of its expanding shroud of dust and gas. Such a thinning of the star's dusty veil would allow more of the star's light to shine through it. "Don't believe anyone who says that it supports any existing theory," says Davidson. "Frankly, we don't understand what is happening." He hopes additional observations will help solve the mystery.

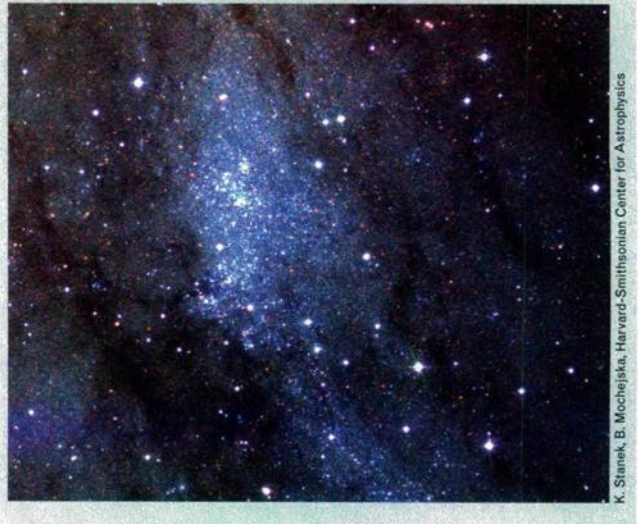
If the brightening continues, Eta Carinae may become an "easy-to-see" object visible to the naked eye. Like a good score in golf, the lower the magnitude value, the brighter the object. Those with magnitude 6 or lower are visible with the naked eye, and Eta Carinae might brighten from 5th to 4th magnitude. The star in Carina is observable during various times of the year from as far north as Florida and in the Southern Hemisphere. — Robert Naeye

The Hubble Space Telescope captures an increase in brightness of Eta Carinae. The star's nebula — material thrown off in a massive eruption — was first observed in the 1840s.



Jon Morse, Kris Davidson, NASA

THE LOCAL GROUP



K. Stanek, B. Mochejska, Harvard-Smithsonian Center for Astrophysics

This image of NGC 206, a rich star-forming region in the Andromeda Galaxy, or M31, was produced by Barbara Mochejska, a graduate student at the Harvard-Smithsonian Center for Astrophysics. She combined blue, visual, and infrared images. Mochejska, a member of a project headed by Krzysztof Stanek and Dimitar Sasselov, is determining distances to two Local Group galaxies, M31 and M33. The distance-estimates will be made with the help of detailed measurements of detached eclipsing binary stars in the two galaxies. The measurements will reveal the stars' sizes, orbital velocities, and amounts of light they produce.

COSMOLOGY

Universe: 12-15 Billion Years Old

▶ Using the Hubble Space Telescope, an international team of 27 scientists has estimated the rate at which the universe is expanding. Scientists have hotly debated the rate ever since Edwin Hubble discovered in 1929 that galaxies were speeding away at rates proportional to their distances from Earth.

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Jeffrey Newman (University of California at Berkeley), and NASA

This Hubble Space Telescope image shows the spiral galaxy NGC 4603 in Centaurus. Key Project astronomers measured the distance to this galaxy at 108 million light-years, which helped them calculate the Hubble constant.

ies, two members of this so-called Key Project said during a May 25 news conference at NASA headquarters in Washington that the expansion rate, or Hubble constant, is 70, plus or minus 7. That means that galaxies are traveling away from Earth at 70 kilometers per second per megaparsec. (A megaparsec is equivalent to 3.26 light-years.) The speed with which galaxies recede from us increases by roughly 160,000 miles per hour (about 250,000 kph) for every megaparsec farther from Earth.

The team used a Hubble constant of 70, plus or minus 7, to compute the universe's age — about 12 to 15 billion years, depending on how much matter the universe contains and whether the expansion rate is speeding up. "This is a big step forward," says Key Project co-leader Wendy Freedman of the Observatories of the Carnegie Institution of Washington.

However, a leading scientist scoffs at the new results. "It's a comedy of advertising and marketing of a product that we believe is faulty," says Allan Sandage, a fellow Carnegie Observatories astronomer. Sandage, who uses different methods and data, says his team calculates a Hubble constant of 58, plus or minus 2.

Many astronomers note that all the credible estimates are getting closer to one another. In past years, astronomers have vehemently debated Hubble constant values ranging from 40 to 100.

"Objectively, one would say that we all agree, it's just that we don't agree that we all agree," says Key Project co-leader Jeremy Mould of the Australian National University. Sandage counters, "We do not agree with their result, and we believe they have made a fundamental mistake."

Yale University astronomer Brad Schaefer takes a neutral stance. "The answer is almost here," he says. "When you take all the different methods and average them together, you're in the low 60s. If you pick the low 60s, you'll make friends with nobody, but nobody is going to kill you either."

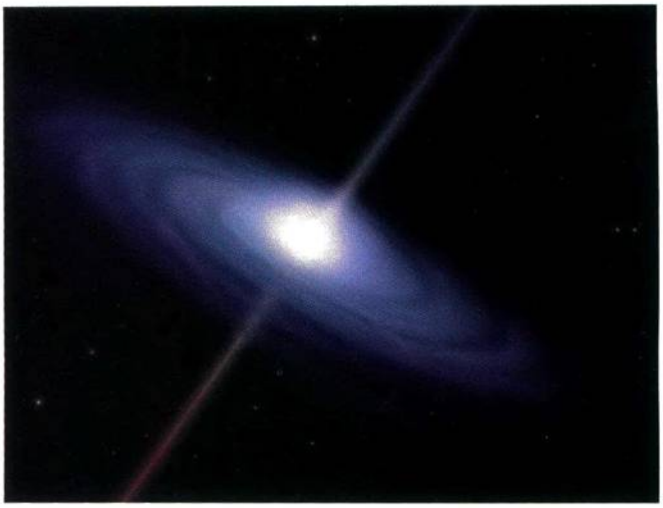
BLACK HOLES

'Quiet' Black Holes Detected in Nearby Galaxies

▶ Theories about black holes and the roles they play in the lives of galaxies sometimes seem like tinker-toy constructions to be taken apart and put back together in a variety of ways. Now, another piece to the puzzle has been uncovered.

Astronomers know that ordinary-size black holes in younger galaxies glow with emitted x rays. However, only a small percentage of supermassive black holes lurking at the center of the oldest, largest galaxies fit that description. The great majority of these huge black holes seemed to produce no x rays. The quiet giants — each with a mass of about 1 billion suns compressed into a region about the size of our solar system — were thought to exist incognito, without radiation. However, in April, Tiziana Di Matteo of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, and Steven W. Allen of the Institute of Astronomy in Cambridge, England,

Most supermassive black holes in the oldest, largest galaxies seem to be dead; however, astronomers recently found small amounts of x rays coming from these quiet giants.



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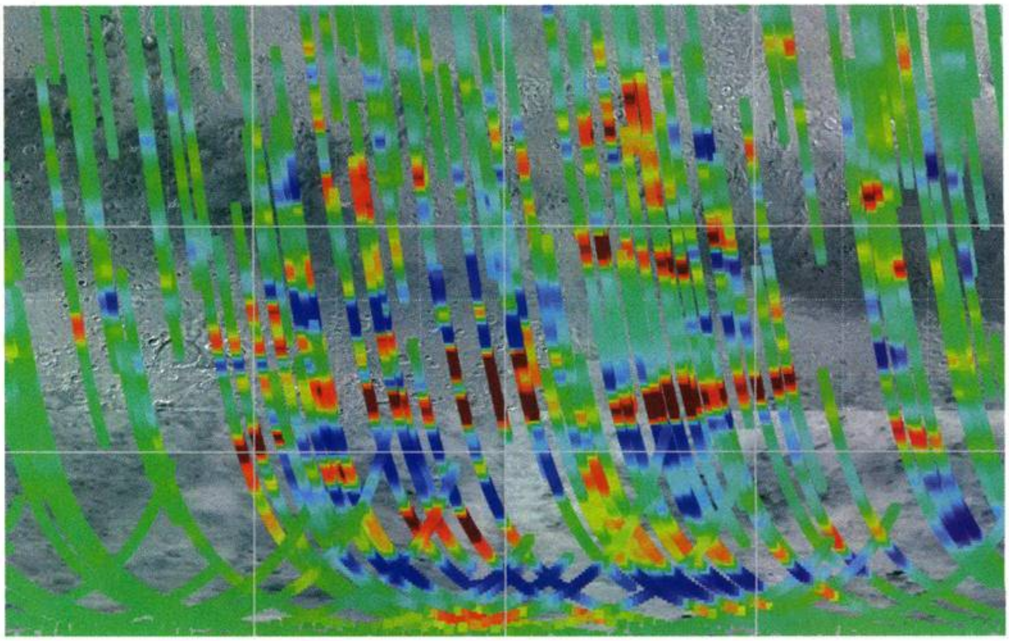
presented evidence that supermassive black holes in six large nearby galaxies leak small amounts of x rays. Using data collected by satellite, they found distinctive, highly energetic x rays coming from the galaxies. "We cannot explain this light as being due to any other source," says Di Matteo.

The light may provide clues to the universe's unexplained x-ray background radiation and appears to support theories of Di Matteo's Harvard colleague Ramesh Narayan and others. They believe the slower rate of material accretion in black holes of older galaxies should produce small amounts of hot x rays.

The successful search for the quiet black holes is tied to a bigger question, says Stuart Shapiro, professor of physics and astronomy at the University of Illinois at Urbana-Champaign: "At what stage do black holes form?" He says black holes could lie in the center of old and young galaxies. "Clearly, one could argue from this that black holes form early in the life of each galaxy."

— Neal Singer



NASA, Jack Connerney, Mario Acuña, Carol Ladd

The false blue and red colors represent invisible fields of magnetism detected on the martian crust. Adjacent bands have opposite magnetic orientations.

MARS

Early Martian Magnetism Tape-Recorded in Rock

▶ Mars apparently followed the credo of a rock star: live fast, die young. New results from Mars Global Surveyor (MGS) reveal that the planet enjoyed a hyperactive youth, when a molten metallic interior generated a powerful magnetic field. The active interior possibly rearranged the martian surface much like the so-called plate tectonics on Earth. The surprising results, reported in the April 30 issue of *Science*, were based on the detection of zebra-like stripes of magnetized martian crust.

Scientists involved in the project say the stripes formed in the first few hundred million years in Mars's life when magma flowed up through long cracks on its surface. Iron in the magma would have been magnetized in alignment with the locally prevailing magnetic field. As the magma cooled and solidified, the iron preserved a record of the field like a giant tape recorder. The MGS magnetometer shows that parallel stripes of martian soil alternate in their polarity, indicating that the martian magnetic field reversed direction every few million years, much the way that Earth's magnetic field periodically flip-flops.

Seafloor spreading at Earth's mid-ocean ridges is the driving force behind plate tectonics — the movement of large plates in Earth's crust. The similar alternating magnetic patterns on Mars suggest — but do not prove — that the Red Planet once had plate tectonics. "It's so suggestive and attractive, and since we tend to be geocentric, it seems natural to refer to plate tectonics," says University of Delaware geophysicist Norman Ness, a member of the Global Surveyor magnetometer team.

Not all scientists are convinced. "These long magnetic stripes don't really exhibit the same kind of symmetry that you see in Earth's spreading centers," says Cornell University planetary scientist Jim Bell. "This is a fantastic discovery, but I think the evidence for martian plate tectonics is far from conclusive."

Ironically, a flaw in the spacecraft allowed its magnetometer to make the new measurements. A glitch with one of the two solar panels forced MGS to spend an extra year around Mars gently shifting from an elliptical orbit to a circular one. The magnetometer took readings from the low points in those elliptical orbits, only 120 miles or less above the martian surface.

Unfortunately, Surveyor's other three instruments — its camera, altimeter, and spectrometer — which were designed to operate during a 240-mile-high circular mapping orbit, remained idle until the circular orbit was achieved in March 1999. "There was always just one guy smiling at the early meetings," says Mario Acuña, leader of Goddard Space Flight Center's magnetometer team.

No magnetic zones were detected in most of the northern hemisphere. "The dynamo only lasted for sev-

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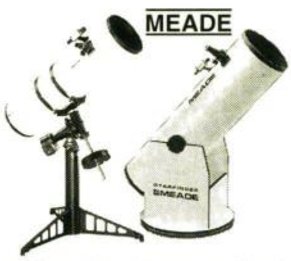

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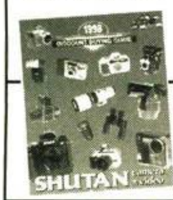

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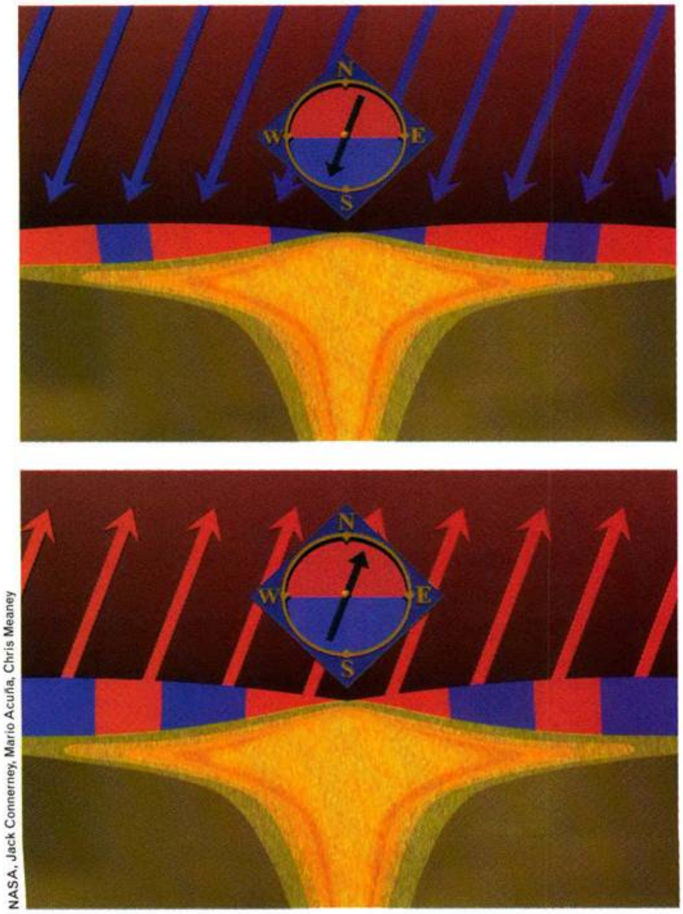
eral hundred million years at best, which is expected because Mars is small. It lost its heat faster than a larger body, such as Earth, so the dynamo just stopped," says Acuña. He estimates that the martian dynamo might have been 5 to 10 times stronger than Earth's present-day dynamo.

A compass would not work on Mars because it doesn't currently have a global magnetic field like Earth's. However, the MGS magnetometer recorded strong localized magnetic sources all over Mars's southern hemisphere, which is dominated by ancient highlands peppered by impact craters. The magnetometer found parallel east-west stripes of alternating polarity in two regions — Terra Sirenum and Terra Cimmeria. The stripes appear to average 600 miles (1,000 km) in length, with the longest stretching for 1,200 miles (2,000 km). The stripes are about 120 miles (200 km) wide.

These images are an artist's conceptions of the process that may have generated magnetic stripes in the crust of ancient Mars. In the upper image, the blue arrows and compass needle indicate the direction of the magnetic field. The yellow-orange shape represents a pool of molten rock (magma) upwelling beneath the martian crust. The red and blue bands are magnetized crust on either side of a spreading center, or rift. Periodically, the global magnetic field reversed direction, which is illustrated in the bottom image, with the red arrows and compass needle indicating a reversed direction of the magnetic field.



NASA, Jack Connerney, Mario Acuña, Chris Meaney

Asteroid Belt Lurking Nearby?

A new study based on computer modeling suggests that a hitherto undiscovered asteroid belt could lurk just beyond Earth's orbit. The authors of the study searched through the catalogs of near-Earth objects and found three recently discovered asteroids — 1996 XB_{27}, 1998 HG_{49}, and 1998 KG_3 — in the zone where they predicted such objects could exist. For more, go to www.astronomy.com/horizon.html.

Colliding Spiral Galaxies

Astronomers compiling a catalog of spiral galaxies have discovered that collisions between such galaxies, as well as near-collisions, are more common than had been thought. "It means there were more close encounters," says Jay Frogel, professor of astronomy at The Ohio State University. Frogel and Paul Eskridge, a postdoctoral research fellow, compiled pictures of more than 200 nearby spiral galaxies over the past five years. For more, go to www.astronomy.com/horizon.html.

The Ohio State University Spiral Galaxy Survey

Spiral galaxy NGC 2442 shows evidence of a recent interaction.

Middleweight Black Holes

Heavyweight black holes that pack the gravitational punch of a billion suns have more to contend with than mere lightweights a few times heavier than our sun. Astronomers have discovered "middleweights" weighing in at 100 to 10,000 suns. Astronomers at NASA and Carnegie Mellon University have independently found evidence for the new type of black holes in spiral-shaped galaxies. For more, go to www.astronomy.com/horizon.html.

Satellite Jitters Tamed

NASA had a problem and Chuck Clagett solved it. The space agency wanted to rapidly slew the Submillimeter Wave Astronomy Satellite but avoid jitters that lead to blurry images. Clagett, an engineer, accomplished the task by designing an improved version of a reaction wheel, a flywheel-like device, that when spun, makes the spacecraft pivot in the opposite direction. For more, go to www.astronomy.com/horizon.html.

NASA/GSFC

Clagett's invention takes the jitters out of satellites' motions.

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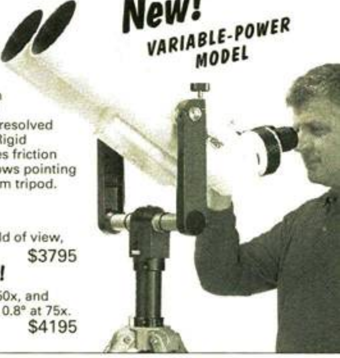

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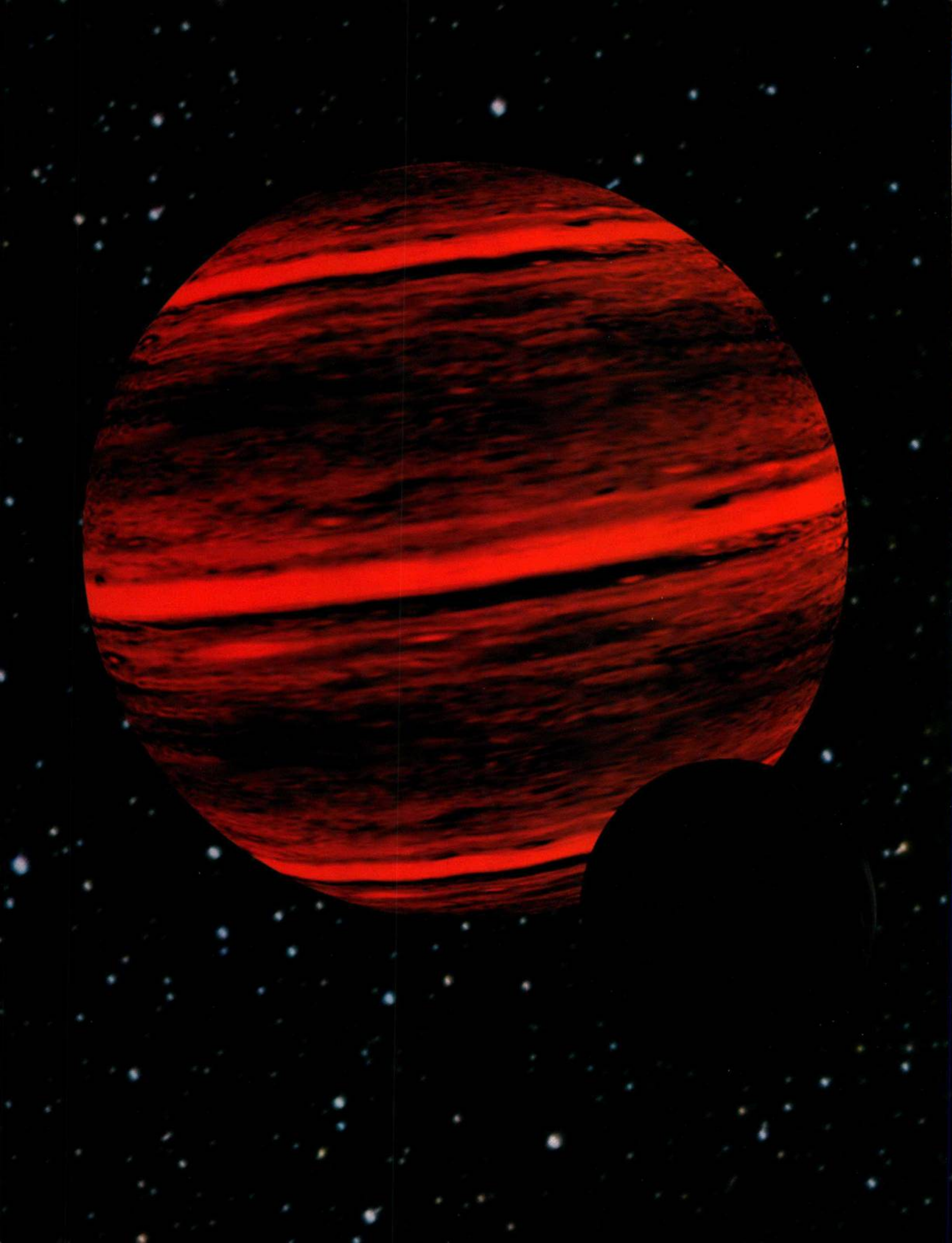


The Little Stars That Couldn't

Bigger than planets but too small to shine like stars, brown dwarfs occupy the murky realm in between.

by Robert Naeye

Life was easy for astronomers before 1995: There were stars, and there were planets. Stars were big, bright, searing hot objects that produced energy by fusing hydrogen atoms in their cores. Planets were small, cool objects that orbited stars and generated little if any energy. Stars formed from gas clouds collapsing under the influence of gravity; planets formed by sweeping up rock, ice, and gas inside a disk.

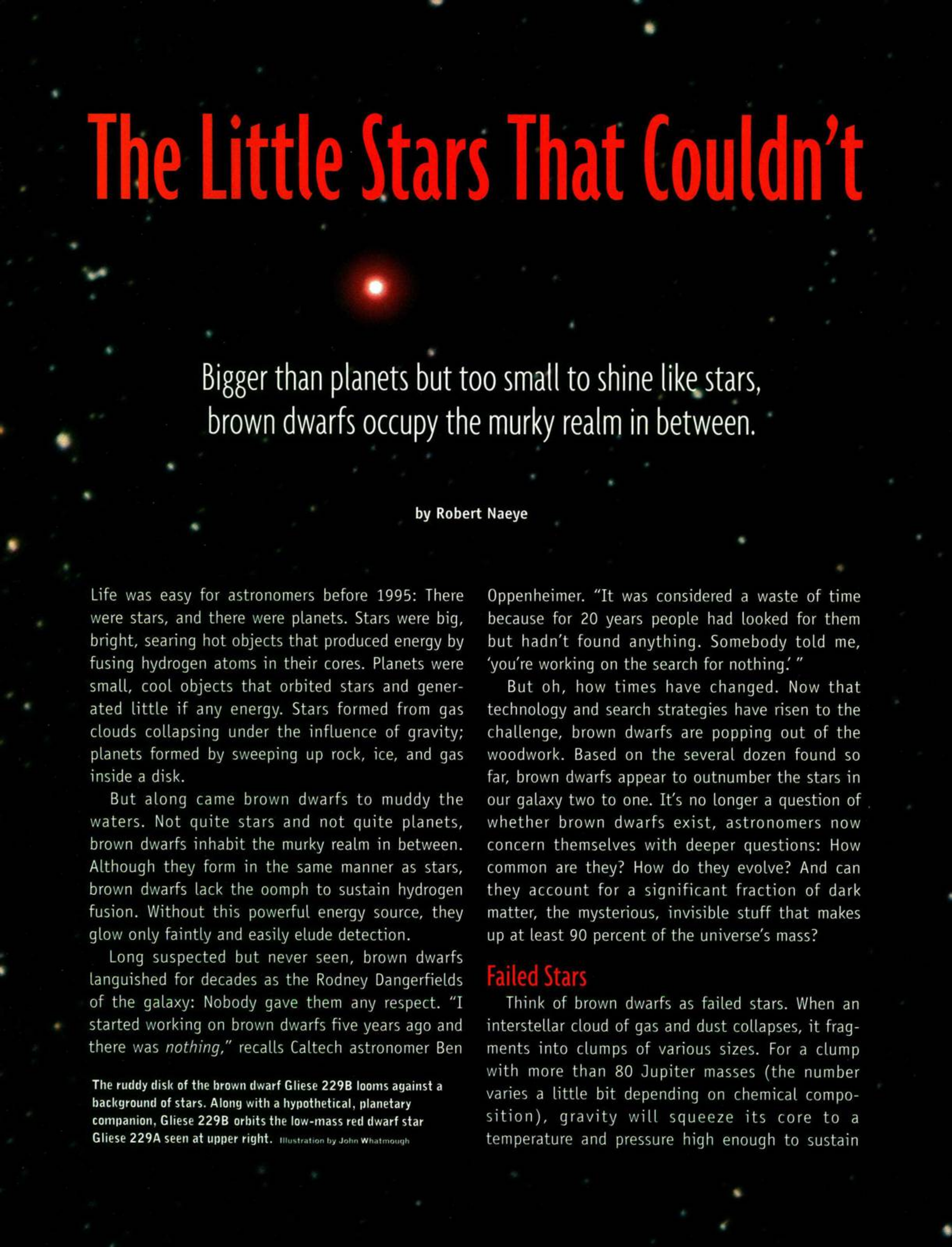
But along came brown dwarfs to muddy the waters. Not quite stars and not quite planets, brown dwarfs inhabit the murky realm in between. Although they form in the same manner as stars, brown dwarfs lack the oomph to sustain hydrogen fusion. Without this powerful energy source, they glow only faintly and easily elude detection.

Long suspected but never seen, brown dwarfs languished for decades as the Rodney Dangerfields of the galaxy: Nobody gave them any respect. "I started working on brown dwarfs five years ago and there was *nothing*," recalls Caltech astronomer Ben Oppenheimer. "It was considered a waste of time because for 20 years people had looked for them but hadn't found anything. Somebody told me, 'you're working on the search for nothing.' "

But oh, how times have changed. Now that technology and search strategies have risen to the challenge, brown dwarfs are popping out of the woodwork. Based on the several dozen found so far, brown dwarfs appear to outnumber the stars in our galaxy two to one. It's no longer a question of whether brown dwarfs exist, astronomers now concern themselves with deeper questions: How common are they? How do they evolve? And can they account for a significant fraction of dark matter, the mysterious, invisible stuff that makes up at least 90 percent of the universe's mass?

Failed Stars

Think of brown dwarfs as failed stars. When an interstellar cloud of gas and dust collapses, it fragments into clumps of various sizes. For a clump with more than 80 Jupiter masses (the number varies a little bit depending on chemical composition), gravity will squeeze its core to a temperature and pressure high enough to sustain



The ruddy disk of the brown dwarf Gliese 229B looms against a background of stars. Along with a hypothetical, planetary companion, Gliese 229B orbits the low-mass red dwarf star Gliese 229A seen at upper right. Illustration by John Whatmough hydrogen fusion. With this powerful energy source at its disposal, an object will shine steadily for millions, billions, or even trillions of years. Astronomers call these objects stars.

But what of those clumps that don't quite reach the critical threshold? Lacking the magic 80 Jupiters worth of mass (equivalent to 0.08 the mass of the sun), these objects — brown dwarfs — retain their stellar chemical composition and may even ignite fusion for a few million years. Without a sustainable internal energy source, however, brown dwarfs are destined to fade slowly like the Cheshire cat of *Alice in Wonderland* as they radiate into space the gravitational heat leftover from their formation.

The discovery of brown dwarfs in 1995 came as no surprise to many astronomers. After all, just because objects can't sustain fusion below 80 Jupiter masses doesn't mean that collapsing gas clouds won't make them. As far back as 1963, University of Virginia astronomer Shiv Kumar predicted that the star formation process would produce objects below the 80-Jupiter-mass threshold. Astronomers initially called these hypothetical objects "black dwarfs." In 1975, Jill Tarter, who currently works at the SETI Institute, coined the term "brown dwarf" in her Ph.D. thesis. She recalls, "The use of the term 'black dwarf' was inappropriate because it had already been used to describe the end phase of a fully evolved star as it cooled from the white dwarf stage." (Still, brown dwarfs are not brown. See page 43 for details on *Astronomy*'s contest to come up with a better name.)

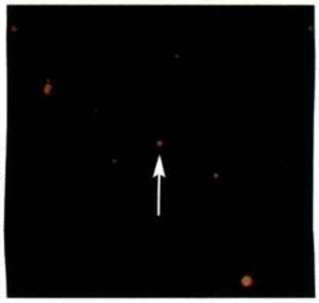
The problem was finding these objects, which everyone realized would be extremely faint. For years, astronomers invested a great deal of time and effort to bag this elusive quarry, but as Harvard University brown dwarf hunter John Stauffer notes, "There were a lot of false Eureka moments."

Mining the Pleiades

Years of frustration came to an end in 1995 when the discoveries of three bona fide brown dwarfs were announced. Two of them were free-floating objects in the Pleiades (M45), a cluster of young stars about 400 light-years away. The third was found only 19 light-years from Earth, orbiting a low-mass red dwarf star called Gliese 229.

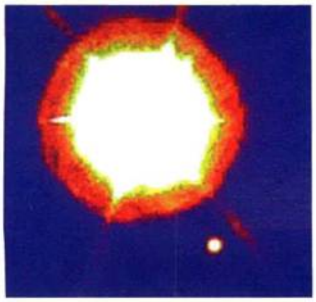
One of the Pleiades' brown dwarfs goes by the prosaic name PPl 15. John Stauffer discovered this object in 1989 with the 5-meter Hale Telescope on Palomar Mountain. PPl 15 was the faintest Pleiad known at the time, but was it a brown dwarf or a faint, low-mass star? Based on its luminosity, it was close to the 80-Jupiter-mass borderline.

An extremely faint member of the Pleiades, Teide 1 (arrow), contains ample lithium — a strong sign that it is a brown dwarf.



Rafael Rebolo (AIC), et al.

A 25-Jupiter-mass brown dwarf appears as a tiny dot below its stellar companion, the young, low-mass star G196-3.



Brown Dwarf Fun Facts

Dumping more mass on a brown dwarf doesn't make it bigger, it just makes it denser. A 70-Jupiter-mass and 20-Jupiter-mass brown dwarf are both about the size of Jupiter.

From up close, a young brown dwarf would look like a low-mass star, but an old brown dwarf would look more like Jupiter.

Brown dwarfs aren't brown, they would look red to the naked eye.

Brown dwarfs radiate most of their energy in infrared light.

There's at least a 50–50 chance that a brown dwarf lurks within 4 light-years, the distance to the sun's nearest stellar neighbor.

Some brown dwarfs spin so fast that they complete one rotation in less than an hour.

Planets have rock-ice cores; brown dwarfs have hydrogen cores.

The average density of a brown dwarf is about 70 grams per cubic centimeter, which is 5 times the density at the center of Earth.

The ambiguity stemmed from the youthfulness of the Pleiades. The stars in the cluster are only about 125 million years old, mere infants on the cosmic timescale. At that tender age, brown dwarfs are still hot, roughly 2300 kelvins (3700° F), and thus hard to distinguish from low-mass stars, which have the same temperature and luminosity. Astronomers realized that the Pleiades was a fertile hunting ground for brown dwarfs because they'd still be hot, and thus relatively bright, but some way was needed to discriminate between brown dwarfs and low-mass stars.

In 1992, Spanish astronomers Rafael Rebolo and Eduardo Martín and Italian astronomer Antonio Magazzù (all of whom worked at the Astrophysical Institute of the Canaries) proposed what's known as the lithium test. As stars fuse hydrogen into heavier elements, they destroy lithium, the third lightest element. Stars aren't born with much lithium, only about one atom per billion, so any low-mass star will destroy lithium within 100 million years. Any cool object bearing lithium has to be a brown dwarf.

At the time Stauffer found PPl 15, there weren't any telescopes big enough to detect the weak spectral fingerprint of lithium. So for several years, the status of PPl 15 remained in limbo. Finally, at a June 1995 conference, a team including Gibor Basri and James Graham of the University of California at Berkeley and Geoff Marcy of San Francisco State University reported lithium in PPl 15. The key was the new 10-meter Keck Telescope on Mauna Kea in Hawaii. Most astronomers were satisfied that PPl 15 was a genuine brown dwarf. But its luminosity put it on the borderline, and some of its lithium had been depleted. Maybe PPl 15 was a star that just hadn't had enough time to destroy all its lithium.

At just about the same time lithium was detected in PPl 15, Rebolo, Martín, and graduate student Maria Rosa Zapatero-Osario were studying a much fainter Pleiad called Teide 1. Its low luminosity and reddish color, which suggested a cool temperature, made it hard to imagine that this object could be anything but a brown dwarf. And sure enough, when Rebolo and Martín teamed up with Basri and Marcy in November 1995 to take its spectrum with the mighty Keck Telescope, they found that Teide 1 had retained its full complement of lithium. Based on its luminosity and age, theoretical models of how fast brown dwarfs cool pinned Teide 1's mass at 30 to 50 Jupiters.

Although few astronomers question Teide 1's brown dwarf status, not all are satisfied. Todd Henry of Harvard University notes that questions still remain about the age of the Pleiades, the cooling rate of brown dwarfs, and even the behavior of lithium in low-mass stars. "You've got to have the mass," says Henry. "All this lithium stuff is unproven. Some of the Pleiades dwarfs will probably turn out to be brown dwarfs, but some with lithium will not be."

Since 1995, several groups have collectively chalked up about 20 additional brown dwarfs in the Pleiades. One of the objects found by Rebolo and Martín, Roque 25, is so faint that they estimate its mass to be a mere 35 Jupiters.

The Coolest Brown Dwarf

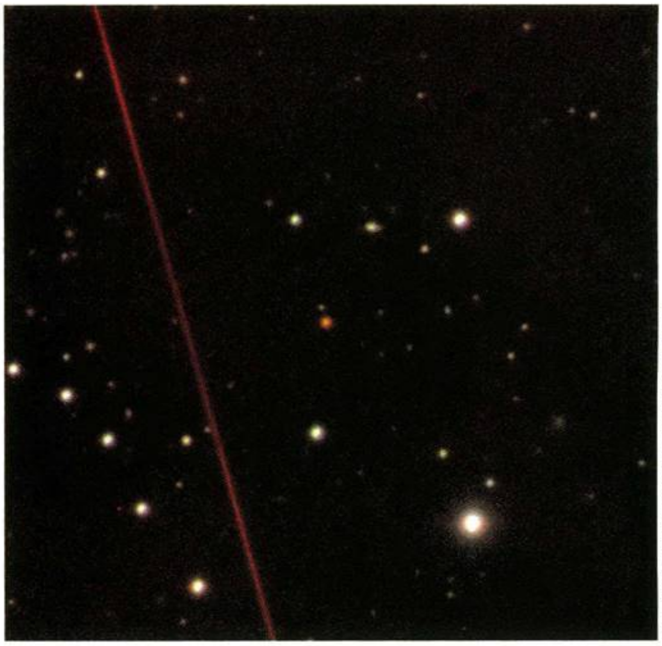
At the same time astronomers were combing the Pleiades, a group of Caltech and Johns Hopkins University researchers including Ben Oppenheimer, Tadashi Nakajima, Shrinivas Kulkarni, and David Golimowski was looking for brown dwarf companions to ordinary stars. To bag their faint quarry, the team blocked out the star's light by using a special masking device called a coronagraph attached to the 1.5-meter telescope on Palomar Mountain.

In October 1994, the team aimed the telescope at the cool, 8th-magnitude red dwarf star Gliese 229, 19 light-years from Earth on the border between Lepus and Canis Major. The image revealed a faint speck next to the star. Observations a year later confirmed that the object shared Gliese 229's motion across the sky, virtually confirming that the two were gravitationally bound. The object, dubbed Gliese 229B, appears to be separated from the primary star by a distance slightly larger than Pluto's distance from the sun. The companion's luminosity is a mere one-tenth that of the faintest star, meaning Gliese 229B is almost certainly a brown dwarf.

At an October 1995 conference in Florence, Italy, the discovery team clinched the case with a stunning announcement: Gliese 229B's spectrum revealed large doses of methane and water vapor. That places the composition of Gliese 229B's upper atmosphere remarkably close to that of Jupiter and even Saturn's large moon Titan — and far away from any star. The presence of methane, which is destroyed at temperatures above 1500 kelvins, signifies that Gliese 229B is far too cool to be a star. Said Geoff Marcy of the methane detection, "It's the most beautiful proof that it's a brown dwarf. It looks like a brown dwarf and smells like a brown dwarf — you can almost taste the methane."

The detection of methane has convinced even those astronomers who remain skeptical of the Pleiades brown dwarfs. "I'm cautious about every brown dwarf announcement except one, Gliese 229B," says Henry. "Other than detecting methane in the spectrum, you need a mass."

Gliese 229B's cool temperature — just 900 kelvins (1160° F) — stems from its advanced age. Astronomers think the system is between 1 billion and 5 billion years old. In other words, the brown dwarf has had plenty of time to cool. It provides a sneak preview of what PPl 15 and Teide 1 will look like a few billion years hence. To this day, Gliese 229B remains the coolest known brown dwarf by far. Based on its luminosity and age, astronomers estimate its mass to be between 20 and 55 Jupiters. Its low temperature and proximity to Earth has made Gliese 229B the subject of intense scrutiny.

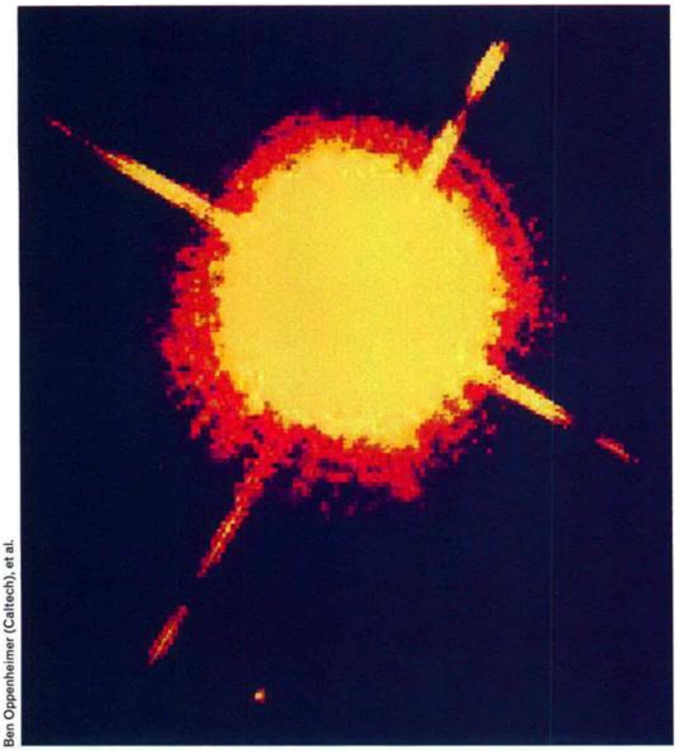

Chris Tinney and the Anglo-Australian Telescope Board

One of the few known binary brown dwarfs, DENIS-P J1228.2–1557, appears in this photo as the single red object at center. The long streak at left is the trail of an Earth satellite that passed through the field.

With a temperature intermediate between that of Jupiter (130 kelvins) and a cool star (2300 kelvins), Gliese 229B serves as a natural laboratory to better understand the physics, chemistry, and even meteorology of planetlike objects. "We've had nine planets to study, and now we have this new object that's between a planet and a star," says New Mexico State University planetary astronomer Mark Marley. "It's at the interface of astrophysics and planetary science. Scientists in the two fields are starting to talk to each other."

The first extraterrestrial weather report came in early 1997, when Marley, Keith Noll of the Space Telescope Science Institute, and Tom Geballe of the Joint Astronomy Centre took an infrared spectrum of Gliese 229B with the United Kingdom Infrared Telescope. They found an unexpectedly large concentration of carbon monoxide (CO) in the brown dwarf's upper atmosphere. In these cool layers, carbon should primarily be found in methane (CH_4) rather than carbon monoxide. This provides strong evidence that carbon monoxide is being dredged up from warmer layers by convection, the same process that causes bubbles to rise in a pot of boiling water.

While Gliese 229B's upper atmosphere appears relatively devoid of dust, the brown dwarf's visible light spectrum indicates a smoggy haze layer deeper down. The haze makes Gliese 229B much fainter in visible light than it would otherwise be. Northern Arizona University planetary scientist Caitlin Griffith suggests that ultraviolet light from Gliese 229A initiates photochemical reactions in its companion's atmosphere in much the same way as solar ultraviolet light creates smog over Los Angeles. Griffith's analysis implies that if Gliese 229B were floating free in space rather than orbiting a star, it might look quite different.



Ben Oppenheimer (Caltech), et al.

Nearly lost in the glare of its stellar companion, the brown dwarf Gliese 229B (bottom) puts out just enough light and lies far enough from its host star to be seen by the sharp eye of the Hubble Space Telescope.

The Brown Dwarf Desert

Since the discovery of Gliese 229B, astronomers have eagerly sought more brown dwarf stellar companions. After all, at least half of all stars exist in binary or multiple star systems. If brown dwarfs form like stars, one would think they'd be common around stars too, right?

Wrong. While a few have been found, Geoff Marcy comments, "What's even more remarkable than the discoveries is the *lack* of brown dwarf discoveries around nearby stars." So few brown dwarf companions have turned up that Marcy refers to their absence as "the brown dwarf desert."

UCLA astronomers Eric Becklin and Ben Zuckerman may have found the first brown dwarf companion back in 1988. They spotted an object separated from the white dwarf GD 165 by about 120 times the Earth-sun distance. The object glows coolly at 1800 kelvins and is extremely faint, but its spectrum shows no sign of lithium. GD 165B is either a very low mass star or a high-mass brown dwarf that has burned all its lithium.

Astronomers have recently found two clear-cut brown dwarfs orbiting stars. Last year a group led by Rebolo found a 25-Jupiter-mass brown dwarf orbiting the relatively young, low-mass star G196-3 at about 300 Earth-sun distances. More recently, a UCLA group including Becklin, Zuckerman, Patrick Lowrance, and Richard Webb has snagged a 20-Jupiter-mass brown dwarf orbiting about 100 Earth-sun distances from a newborn star called TWA 5.

Despite these successes, the search for brown dwarf companions has proved frustrating. As Oppenheimer says, "It's disappointing, but what can you do? That's the way it is."

For example, Oppenheimer's group found Gliese 229B but didn't turn up a single brown dwarf around the other 200 stars on its list. The UCLA group has similar results. Golimowski and Henry have used Hubble's infrared camera NICMOS to look for brown dwarf companions; of the 79 stars analyzed so far, they've found one "wishy-washy" candidate, in the words of Henry. The teams that search for extrasolar planets by looking for stellar wobbles have turned up some 20 planets but only a handful of brown dwarf candidates, even though brown dwarfs — being more massive than planets — produce a much larger wobble and so are far easier to detect. Although some brown dwarf stellar companions undoubtedly have faded below the detection threshold, at the moment it appears that only 1 or 2 percent of stars have brown dwarf companions.

Alan Boss of the Carnegie Institution notes that in most binary systems, the two stars are usually within a factor of 10 in mass, meaning brown dwarfs will rarely be found around stars other than the very low mass variety. Boss is quick to add, "If you really want to find a brown dwarf, the best place to look is around another brown dwarf." Astronomers have, in fact, found at least three binary brown dwarfs, and probably many other brown dwarfs will turn out to be binary once they are examined in more detail.

PPl 15 in the Pleiades is one of the binaries, and now that astronomers know that the light they're seeing comes from two components, there's no longer any doubt about its brown dwarf status. The two brown dwarfs lie so close to each other — only 0.03 the Earth-sun distance — that they complete one orbit every 6 days. "It looks like they were trying to make a low-mass star but couldn't get it together," says Basri. Unfortunately, the two are so close to each other that telescopes can't resolve them into individual objects.

Astronomers are particularly excited about one of the other brown dwarf binaries, called DENIS-P J1228.2–1557, because the two components are separated by about as much as the sun is from Jupiter, far enough that the Hubble Space Telescope can resolve them into two distinct objects. By following the orbit over the next 5 to 10 years, astronomers will be able to directly measure the mass of both brown dwarfs. This in turn will help astronomers check how accurately cooling models predict brown dwarf masses.

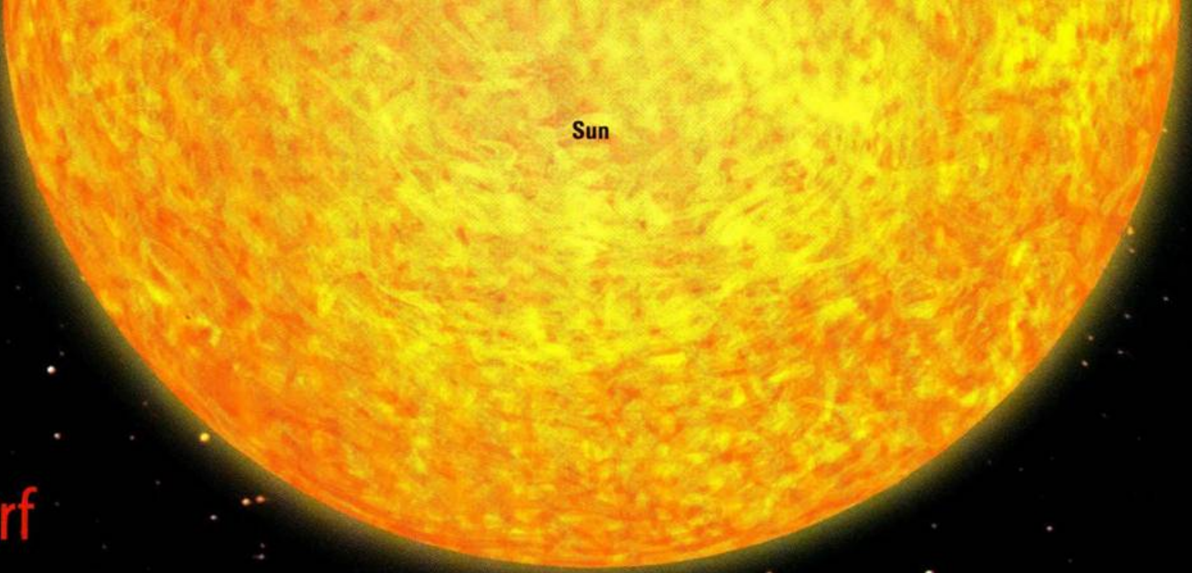
Brown Dwarf Conveyor Belt

Brown dwarfs only rarely seem to orbit stars, but two new infrared sky surveys are harvesting free-floaters by the bushel. As Basri says, "There's no brown dwarf desert out there; there are fields and meadows of them, but not as companions to solar-type stars."

One of the sky surveys goes by the acronym 2MASS, short for 2 Micron All-Sky Survey (2 microns being the main wavelength of the survey, which is also where brown dwarfs emit much of their energy). Headquartered at UMass (the University of Massachusetts at Amherst) and Caltech's Infrared Processing and Analysis Center (IPAC), 2MASS involves a total of 10 institutions.

Davy Kirkpatrick of IPAC is 2MASS's point man for brown dwarfs. As 2MASS scans the sky of both hemispheres with twin 1.3-meter telescopes in Arizona and Chile, Kirkpatrick identifies potential brown dwarfs and then takes their spectra with the 10-meter Keck Telescope. But 2MASS is finding so many potential brown dwarfs that Kirkpatrick is having a hard time keeping up. "Davy reminds me of that *I Love Lucy* episode where Lucy gets a temporary job as a

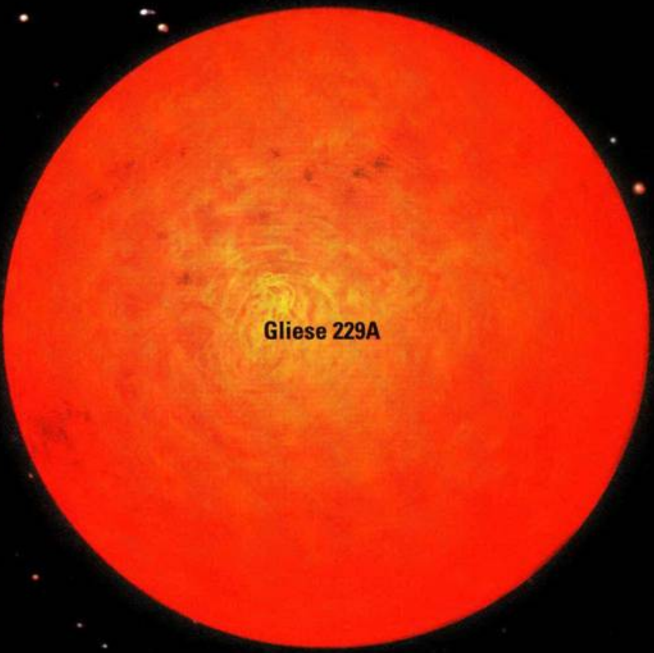
Illustration by *Astronomy*: Elisabeth Rowan; spectra: Ben Oppenheimer (Caltech), et al.

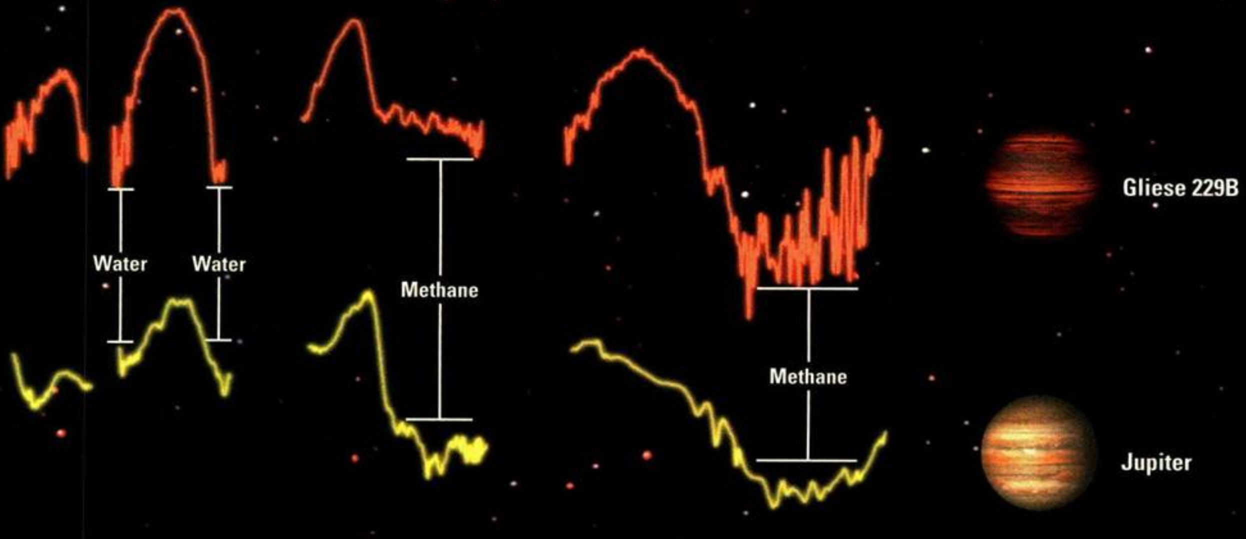


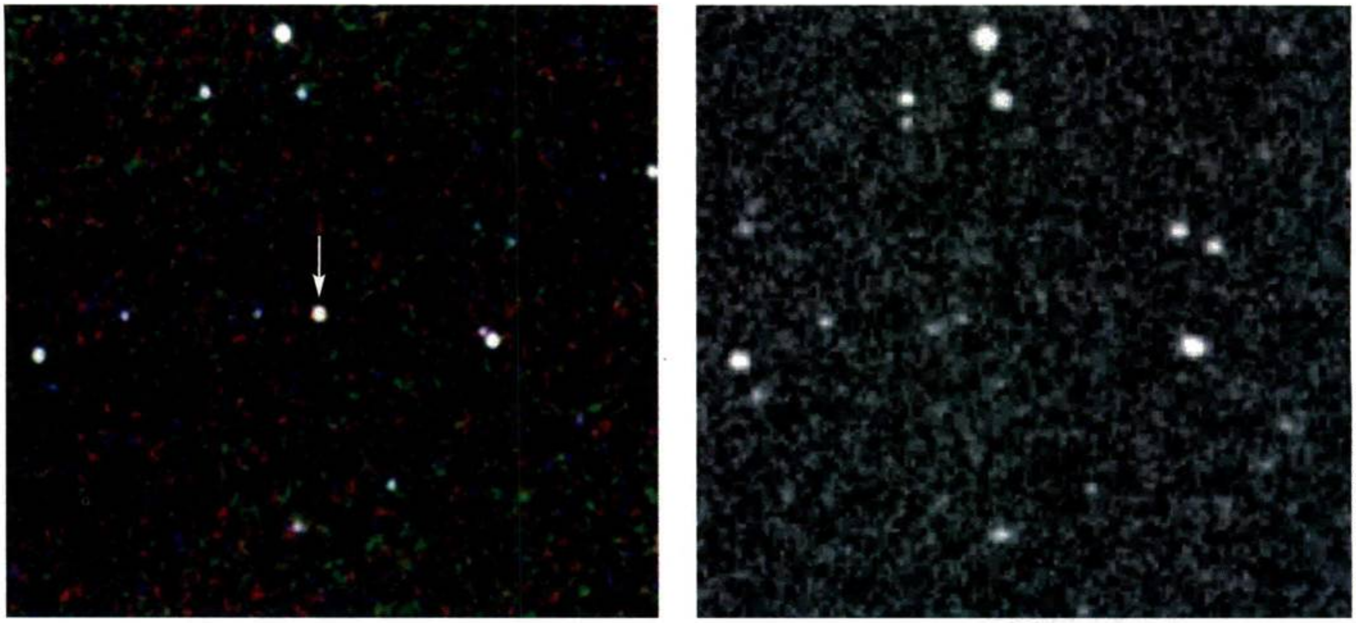
Brown Dwarf Basics

Although calling a class of objects "failed stars" may seem overly harsh, it's a good way to think about brown dwarfs. A brown dwarf forms the same way a star does, out of a collapsing cloud of interstellar gas, but it doesn't have enough mass to sustain the nuclear reactions that define an object as a star. Any body that forms this way but fails to grow beyond about 80 times the mass of Jupiter is destined for brown dwarfdom.

One of the first brown dwarfs discovered, Gliese 229B serves as a good prototype. This cool, dim object is much smaller and fainter than the red dwarf star it orbits, Gliese 229A, which itself is smaller, fainter, and redder than the sun. In fact, Gliese 229B has much in common with Jupiter. Both have approximately the same diameter, even though the brown dwarf possesses a few dozen times more mass than the planet. Even their spectra appear very similar, showing that their upper atmospheres contain large quantities of water vapor and methane, two molecules that would be destroyed quickly in the warmer environment of a star.







The 2MASS infrared survey has turned up dozens of brown dwarfs. Here one pops from a 2MASS image (left) where nothing shows in the optical (right).

Davy Kirkpatrick (IPAC/Caltech), et al.

quality control clerk over the candies that come down a conveyor belt," jokes Marcy. "They start coming so fast that Lucy can't do the quality control part, so she starts eating them."

Kirkpatrick doesn't exactly "eat" brown dwarfs, but he is enjoying a feeding frenzy. So far, 2MASS has turned up more than 70 cool objects that could be brown dwarfs, and at least 17 have passed the lithium test. Some of the candidates are so cool and faint that even Keck can't get a spectrum; some of these could be as cool or cooler than Gliese 229B.

Not to be overshadowed, a group of European and Australian astronomers survey the Southern Hemisphere sky with a 1-meter telescope in Chile. DENIS, an acronym for Deep Near-Infrared Survey, has found at least five brown dwarfs and many more good candidates.

The 2MASS and DENIS conveyor belts have chalked up so many cool objects that astronomers have come to realize they need to update the 100-year-old stellar classification scheme. In this scheme, stars are classified by letters according to their spectra. From hottest to coolest, the letters go OBAFGKM (which astronomers remember with the mnemonic Oh Be A Fine Girl/Guy, Kiss Me). Kirkpatrick and Martín have both suggested the letter L for objects cooler than the M class, in the 2000 to 1400 kelvin range. Some of the L dwarfs are stars still in the process of forming, but most are probably brown dwarfs. Kirkpatrick has even suggested the letter T for objects cooler than 1400 kelvins, such as Gliese 229B, Jupiter, and Saturn.

"L dwarfs are all over the place. There are more of them than any other type of star in the galaxy," says Kirkpatrick. "One of the big questions is whether there is one closer than Proxima Centauri, the closest known star to the sun. Statistically, you'd think maybe there would be. If so, I would love to be the one who discovers it."

Even though brown dwarfs are being found in star forming regions, interstellar space, and around stars, they're still lightweights compared with stars. So despite the large numbers of brown dwarfs being discovered, they're not turning up in large enough numbers to account for more than a small fraction of the dark matter that makes up some 90 percent of our galaxy's mass. A recent study led by Caltech astronomer Neill Reid concludes that brown dwarfs make up at most 15 percent of the galaxy's mass. "The bottom line is that if there were equal mass in brown dwarfs and in stars, then we should have detected four times as many L dwarfs as we have found," says Reid.

You Ain't Seen Nothin' Yet

Despite the success of 2MASS and DENIS, they can only detect T dwarfs such as Gliese 229B to about 30 light-years. Theoretically, there should be many more T dwarfs than L dwarfs. "The L dwarfs are just the tip of the iceberg. I think there's this whole Cheshire cat population out there that we just can't detect," admits Kirkpatrick.

Keith Noll echoes the desire of astronomers for more Gliese 229Bs: "Just a few years ago we would have died for any one of these objects, but now I'm starting to feel choosy. Well, another 2000 kelvin brown dwarf, who cares about that? I want to see a cool one."

Fortunately, help will soon be on the way. NASA is scheduled to launch the Space Infrared Telescope Facility in December 2001. SIRTF's extremely sensitive infrared camera should be able to spot Gliese 229B analogs out to 400 light-years. These dwarfs will help astronomers pin down the number of brown dwarfs, how they evolve, and the minimum masses of objects produced in star formation.

But in the meantime, brown dwarf aficionados have plenty to keep themselves busy. "We're standing on top of a mountain looking at the landscape in front of us and seeing that there's a rich variety of areas to explore, but there are a lot of big picture questions that we don't understand at all," says Marley. "It's early, but that's what makes it so exciting. Why are brown dwarfs interesting? One answer: It's all brand new."

Astronomy *associate editor Robert Naeye hopes astronomers turn up a brown dwarf closer than Proxima Centauri so an interstellar mission can be launched in his lifetime.*

Enter & WIN!

What would you call a brown dwarf?

Astronomers agree brown dwarfs would appear red to the human eye, so the name "brown dwarf" is a little misleading. Even though scientists will continue to use that term, we want to know what you'd call these objects. Remember — the name "red dwarf" is already taken and most astronomical objects have one- or two-word names. Five leading brown dwarf experts — Gibor Basri, Davy Kirkpatrick, Mark Marley, Eduardo Martín, and Ben Oppenheimer — will judge the entries and select the winning names in our contest.

Hurry! Entry deadline: August 31, 1999

E-mail your entries to **browndwarf@astronomy.com**

Or send up to three new Brown Dwarf names to:
Brown Dwarf Contest, *Astronomy* Magazine
P.O. Box 1612 • Waukesha, WI 53187-1612

Astronomy

Official Rules

1. *Entries must be received by August 31, 1999.*
2. *There is a limit of three entries per person.*
3. *Please limit your entry and explanation to 25 words each.*
4. *Winners will be selected by an independent panel of judges.*
5. *Winners (and their prize selections) will be announced in* Astronomy's *December '99 "Behind the Scenes" column.*
6. *If winning name is submitted by more than one person, the earliest entry will win.*

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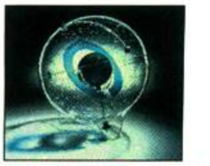

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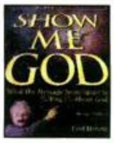

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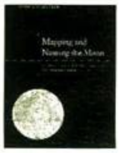

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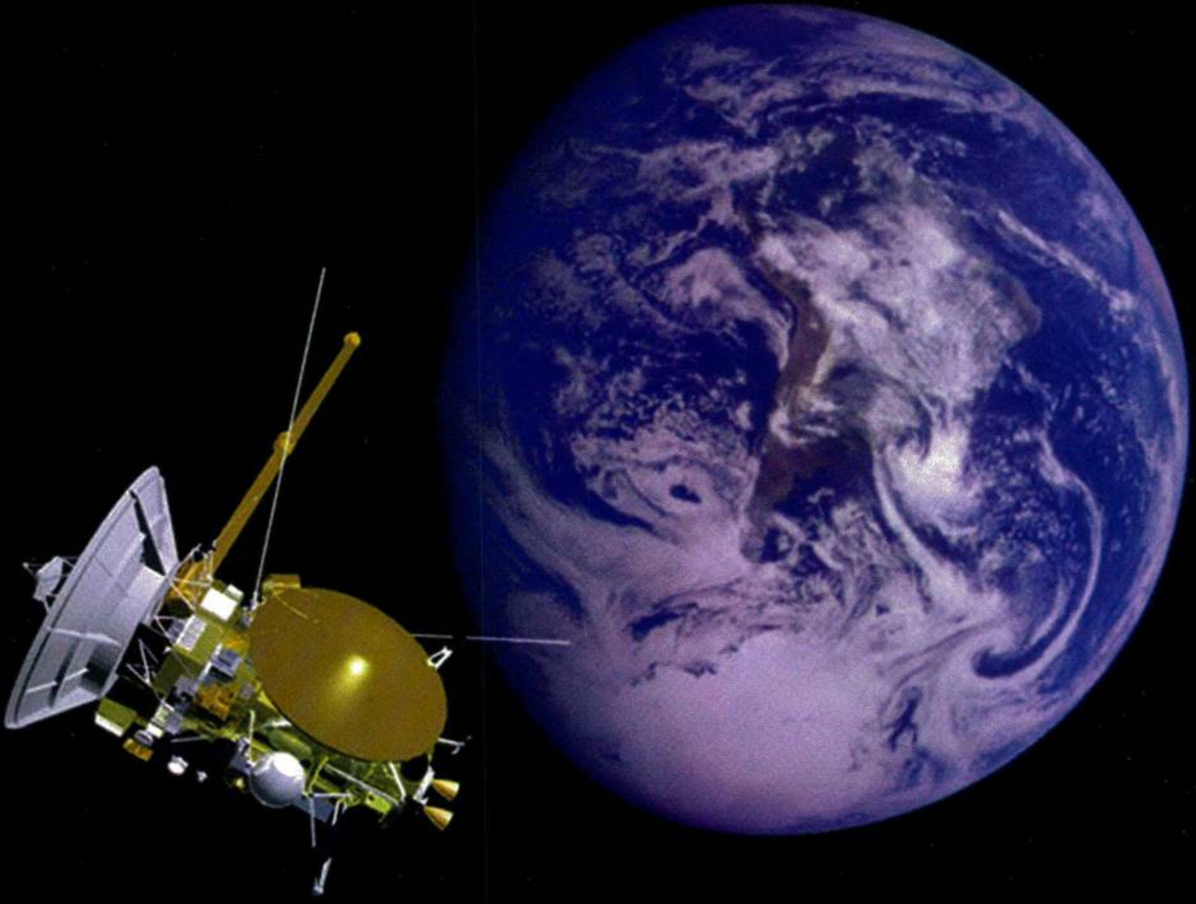


CASSINI'S NUCLEAR RISK

Could this spacecraft shower radioactive plutonium on our atmosphere during its Earth flyby? **by David Grinspoon**

The conflict between space explorers and environmentalists over the Cassini probe breaks my heart. Maybe you thought the battle ended in October 1997 when protesters failed to prevent the successful launch of Cassini, but activists are now gearing up to protest this August's Earth flyby. This spacecraft, which will arrive at Saturn in 2004, is fueled by RTGs (radioisotopic thermoelectric generators) containing 72 pounds of plutonium oxide. Depending on whether you listen to NASA or its critics, the plutonium either has virtually no chance of being released into the environment and even in a worst-case scenario would have negligible health effects, or it could cause a global disaster, killing billions and making wastelands of large areas of Earth. The protesters want NASA to scrap the flyby (and by extension the Saturn mission), and they demand that all planetary missions be powered by clean and safe solar energy. Many planetary probes are solar powered, but the technology to use solar energy near Saturn, where sunlight is a hundred times less intense than here, won't be available any time soon.

This controversy is especially painful for those of us who believe strongly in both environmentalism and space exploration. I have been involved with both for most of my life, and I see them as natural allies. We need planetary exploration in order to gain a deep understanding of our planetary home. We all had our environmental consciousness raised by the first photographs of the whole Earth — a tiny blue ball of life spinning in infinite darkness. The photographers were Apollo astronauts who rode in a craft carrying RTGs.

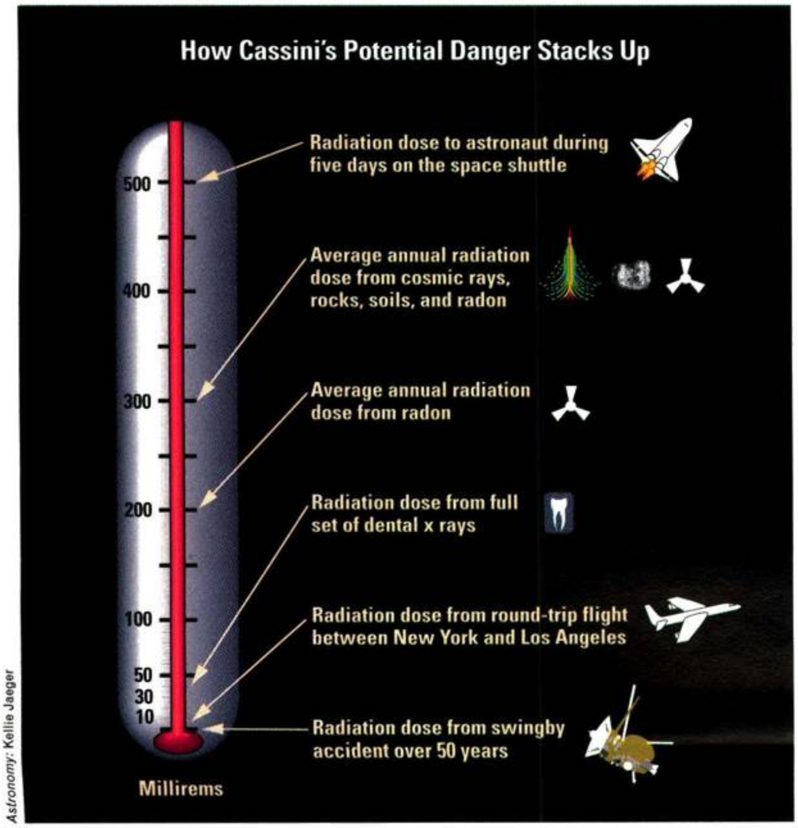
The first time I was involved in political action, I was in a stroller being pushed by my mother in a 1962 march against atmospheric nuclear testing. That protest movement succeeded in part because of compelling scientific evidence provided by leaders such as Nobel Prize-winning chemist Linus Pauling. That same year the first successful probe to another world was launched — Mariner 2 to Venus, a planet that is still teaching us priceless lessons about the greenhouse effect, ozone depletion, acid rain, and global change. Having grown up entranced by the excitement of planetary exploration and frightened by the threat of nuclear destruction, I found it natural to become both a planetary scientist and an antinuclear activist. I regularly took time out from my studies to protest on both coasts and in between, organizing disarmament symposia at college and skipping graduate school classes for demonstrations at the nuclear test site in Nevada.

David Seal/NASA/JPL

So I am deeply disturbed to see the lines being drawn between space science and love for Earth and dismayed by the hyperbole and misunderstanding on both sides in the debate over Cassini. I recently checked out the lovearth website, one of several devoted to opposing the mission. I was greeted with one of those lovely, plutonium-enabled, whole-Earth photos and told that Cassini carries enough plutonium to cause cancer in everyone on the planet. That statement is true but misleading and inflammatory. It is equally true to say that your car has enough mass to kill everyone on Earth (if you ran them all over two at a time). Linus Pauling would never have played so fast and loose with scientific risk assessment. These kinds of statements make it easy for some scientists to dismiss all protesters as crystal-rubbing flakes — which they're not.

On the other side, some of the NASA safety assurances also miss the point. We are told that in the incredibly unlikely case of a plutonium-releasing accident during flyby, the increased radiation exposure of the average American would be very low and that the small number of deaths would represent a negligible increase in the death rate from cancer. This statistical approach can be used to downplay the seriousness of any lethal threat. But we are talking about the potential deaths of many human beings.

THE
WRONG
STUFF
THE SPACE
PROGRAM'S
NUCLEAR THREAT
TO OUR PLANET
KARL GROSSMAN



Astronomy: Kellie Jaeger

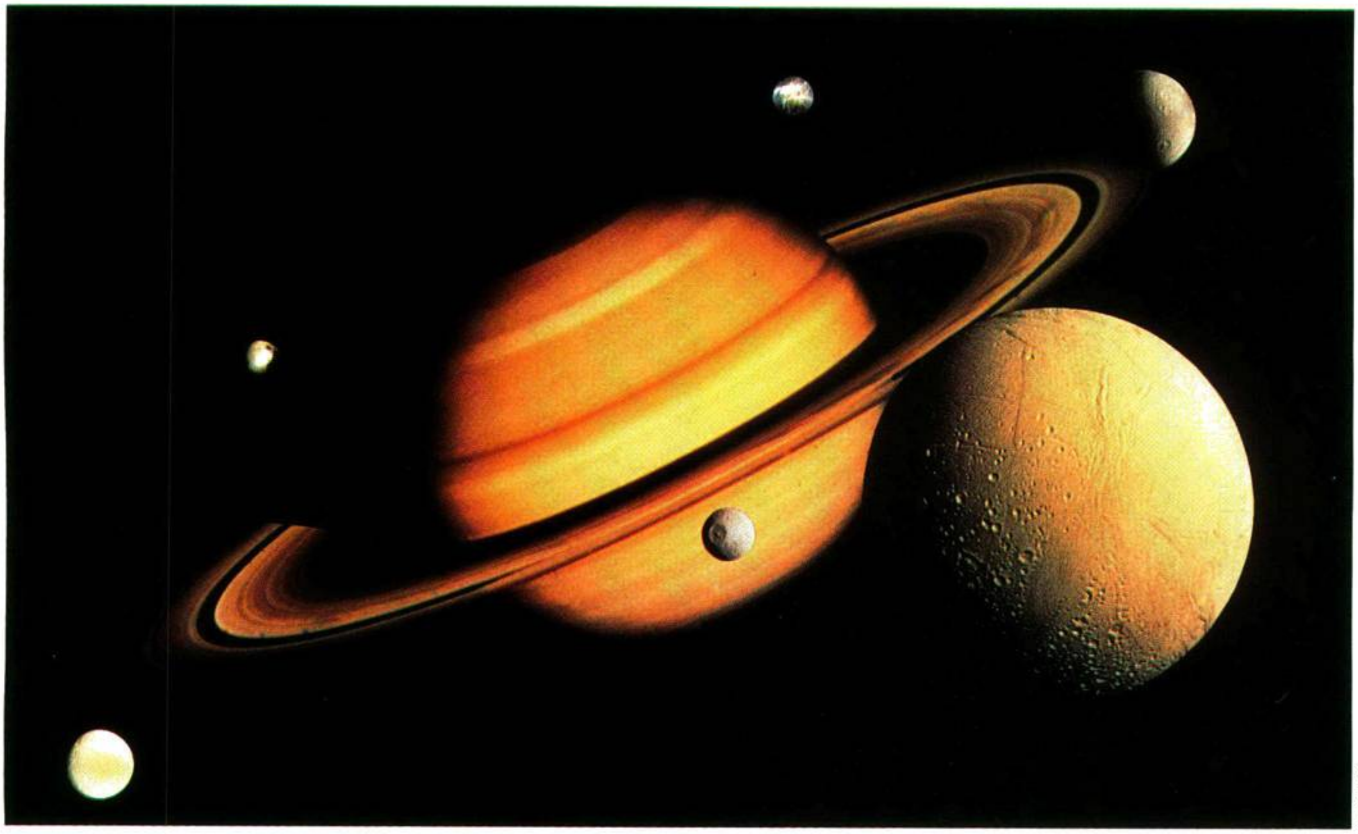
In the chart below, NASA asserts that the risk to world population from a swingby reentry accident is very low. Environmentalists feel it could be much greater, however, causing as many as 30 million deaths according to sources reported on the lovearth website (www.lovearth.net). Right: *The Wrong Stuff* by Karl Grossman details the environmental case against using plutonium in space.

I do know that NASA has not been casual or callous about nuclear safety. It has devoted great ingenuity and vast resources to ensuring the safety of RTGs. Aside from recognizing the possible human tragedy, NASA administrators know that any nuclear accident might spell doom for planetary exploration. The RTGs and their protective casings are ingeniously designed to avoid the dispersal of nuclear material should there be an explosion during launch. The RTG casings have been exposed to forces greater than any that would accompany a launch accident and have passed the test. At any rate, Cassini's flawless launch rendered that part of the argument moot for now.

However, an accident is not impossible later this summer when Cassini zooms past Earth at 42,000 miles an hour to be gravitationally slingshot toward Saturn. An impact at this velocity would be much more dangerous. This kind of accident is extremely unlikely. I am not professing blind faith in our little machines but relying on our knowledge of the basic geometry of space: Space is so big and Earth so small that any mistake in trajectory is far more likely to miss us by thousands of miles than come anywhere near us. NASA estimates the chance at one in a million, and this is the kind of thing NASA is very good at estimating.

Of course, it could happen. If the craft did vaporize in our atmosphere, raining down tiny particles of plutonium, hundreds or even thousands of people might eventually die of cancer. There are so many uncertainties in this estimate that no one can do a very good calculation and the two sides will never agree on the risk. (A recent reading of statements on dozens of websites reveals differences by a factor of 109 between fatality estimates on the two sides.) But we are clearly not talking about a global disaster that could alter the planetary environment. No honest and informed person can make such a claim.

Environmentalists need to pick their language and their battles more carefully and avoid the propagation of outlandish risk assessments that discredit this and other causes. It seems to me that some self-aggrandizing journalists are whipping people into a frenzy over this by preying on their legitimate fears. In the long run, they only sap the strength of the environmental movement by distracting people from other, more pressing battles and estranging space enthusiasts. Personally, I lose a lot more sleep about the tons of plutonium waiting to be mopped up at Rocky Flats (here in my own backyard) and Hanford and other casualties of our nuclear program. And what about the risks of not exploring our solar system? How many skin cancer deaths have already been



NASA/JPL

This montage of the saturnian system was made from images taken by Voyager 1 during its Saturn encounter. Dione appears in the forefront, Saturn rising behind, Tethys and Mimas fade into the distance to the right, Enceladus and Rhea rest off Saturn's rings to the left, and Titan orbits at top.

prevented by the discovery of Earth's ozone hole — in which studies of the atmosphere of Venus played a key role? Almost surely more deaths than Cassini could ever possibly cause.

Planetary exploration is essential for a truly holistic understanding of Earth, its long term history and potential for change, and its relationship to our planetary neighbors. Clues to our earliest roots are spinning among the exquisite rings of Saturn. There we will find knowledge of how our world assembled itself billions of years ago from a ring of debris spinning around the sun. Hints about the origin of life on Earth are lurking among the organic ooze of Saturn's enigmatic ice moon Titan. Still, space explorers need to recognize that support for space exploration may decline if we alienate the environmentally concerned public. We must recognize that people have strong feelings (for good reason) about nuclear materials. Our nuclear program is tarnished by Cold-War madness and environmental thoughtlessness. Even in cases where it might be safe, nuclear power is just not as clean or aesthetically pleasing as solar.

It was not technically possible to retrofit Cassini to be a solar-powered mission. To cancel the flyby and scrap the mission now would be to throw away billions of dollars, decades of hard work, and priceless knowledge to be gained. But we are slowly increasing our solar capabilities in space and we should redouble these efforts. NASA has also been moving toward much smaller, less power-hungry craft. There is talk now of solar-powered missions to Jupiter (where sunlight is one twenty-fifth as strong as here), and perhaps we can learn to use solar power at Saturn and beyond. More of the same creativity and resources that went into RTG design should be invested in solar power for deep-space missions. Large technical obstacles must be overcome and some breakthroughs will be necessary, but NASA has always been good at such things. After Cassini, we should introduce a moratorium on Earth-assisted trajectories that bring craft careening within hundreds of miles of our atmosphere. With a bit more fuel we can go directly to the outer solar system.

This issue is not going to go away after the Cassini flyby. There are some exploration goals for which nuclear may be our only option. We need the Pluto Fast Flyby to complete our initial survey of the solar system. This and any missions to Europa, Uranus, Neptune, and Kuiper-belt objects in the foreseeable future will require nonsolar energy. But we need to listen carefully to the critics, work hard to convince them that our plans are safe, and continue to study alternatives. The chances of an accident are very low, but the risk of losing public support for our essential exploration of the solar system is real. If we allow this to happen, it would be a disaster. This is the unacceptable risk of Cassini. Planetary scientists and environmentalists should not be at sword's point on this issue. Let's work together for safe exploration of our solar system. ■

David Grinspoon, planetary scientist at the University of Colorado, is a contributing editor to Astronomy.

The Spacecraft's Got Swing

An unmanned spacecraft will make a spectacular and controversial rendezvous with Earth this month. On August 16, the Saturn-bound Cassini probe will approach our planet's western hemisphere at about 35,000 miles per hour and, from a safe distance of about 725 miles, do-si-do with Earth's gravitational field. The maneuver, called a gravity assist, will increase Cassini's speed and send it reeling toward Jupiter and finally Saturn. The craft has made two earlier swingbys of Venus, wringing a little bit of energy from each encounter to build up the speed needed for its great leap toward the outer solar system. Its swingby with Earth this month will be no different. And despite the recent concern about the craft's reentry into our atmosphere, the gravity assist is crucial to Cassini's goal. Without the maneuver, the probe would never reach Saturn.

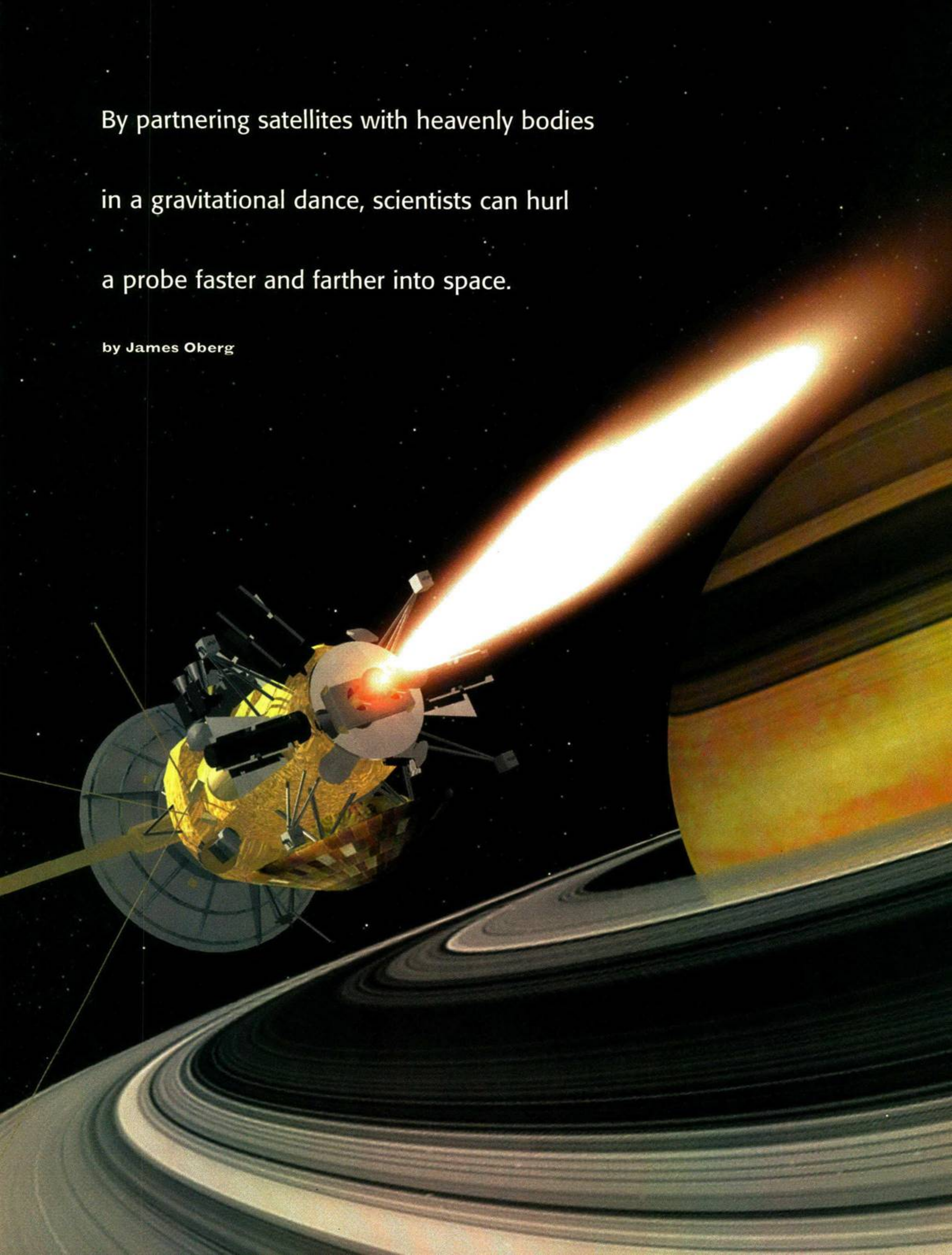
KINGS OF SWING

Cassini is not the first object to receive a gravity assist. Natural objects in our galaxy have experienced this phenomenon for millions of years. In the solar system, the wreckage from planetary births blundered around until it came into the gravitational clutches of planets. Many of the rocky pieces crashed into the massive bodies. But other space debris, just barely within the planet's grasp, got accelerated into the sun or flung along trajectories that broke free of the solar system entirely. The process continues today as a steady trickle of main-belt asteroids leaks into the inner solar system and is quickly — in a few tens of millions of years — swept out by random gravity assists from the planets. Comet astronomers of the 1800s were some of first to recognize these naturally occurring gravity assists. They noticed that when encountering a larger body, a comet appeared to change course slightly.

David Seal, Jet Propulsion Laboratory

By partnering satellites with heavenly bodies in a gravitational dance, scientists can hurl a probe faster and farther into space.

by James Oberg



In the 1920s, the Russian physicist Fridrikh Tsander described the maneuver, and during the 1960s, German engineer Krafft Ehricke, who worked on the V2 rockets with Wernher Von Braun during World War II, had outlined the mechanics of gravity assists in his book *Space Flight*. By the dawn of the Space Age, swingbys were fairly well known. In California, at NASA's Jet Propulsion Laboratory, graduate student Mike Minovitch devised a computer program that analyzed the possibility of using gravity assists on all possible missions. And at the same time and place, graduate student Gary Flandro was also working on a swingby plan. His trajectory proposed using the gravity of four planets to fling a spacecraft from one world to the next. But physicists and engineers at NASA headquarters remained skeptical about the technique.

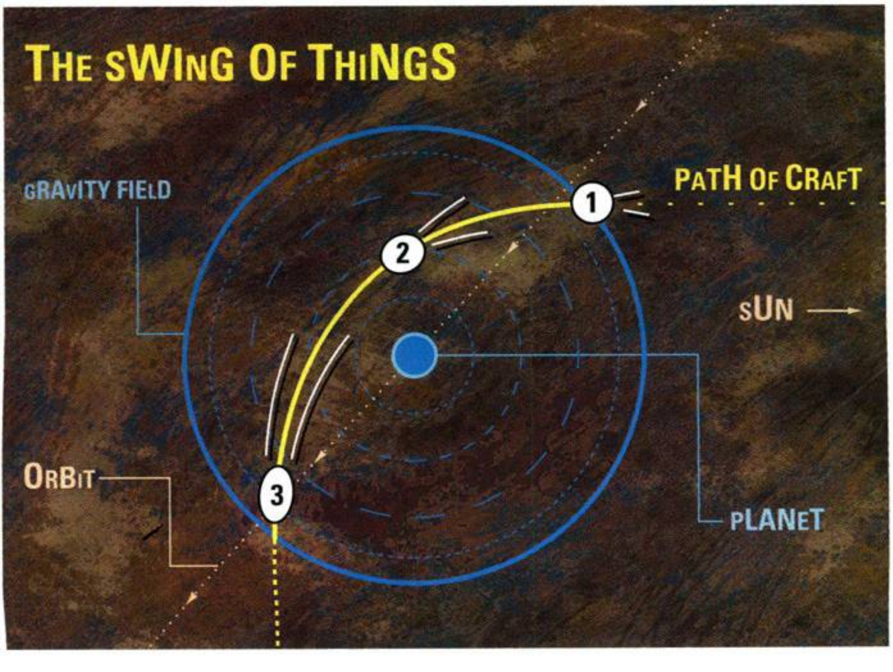
"They were adamant this wouldn't work," says Flandro, who now works as a professor at the University of Tennessee Space Institute.

In hindsight, the skepticism seems ironic. At the same time NASA was raising its eyebrow at swingby technology, its own lunar probes were experiencing a similar phenomenon. Engineers soon realized that they could use the moon's gravity to shape the flight paths of spacecraft. Trajectory designers in Houston designed courses accordingly. They even devised emergency orbits, called free return paths, that used the moon's gravity instead of rocket maneuvers to send a craft back to Earth. In April of 1970, NASA used just such a flight path to bring the crippled Apollo 13 capsule back home safely. NASA was becoming more accepting of the possibility of gravity assists, but the real stamp of approval came in 1974 with Mariner 10. On February 5 of that year, engineers used Venus's gravity to slow Mariner 10's orbit, causing it to fall in toward the sun. That maneuver got Mariner close enough to the sun to swing past Mercury — something that had never been done before.

"By then, everyone had pretty well accepted it," says Flandro. "It opened up the whole solar system."

Indeed, the possibilities for exploration seemed remarkable, and NASA looked more closely at Flandro's plan. He had proposed a swingby route that took advantage of an unusual alignment of Jupiter, Saturn, Uranus, and Neptune. Each flyby would provide the velocity boost necessary to reach the next planet. The design not only economized by using one spacecraft, it also lowered the launch velocity and mission duration so the craft would arrive at Neptune decades earlier than would otherwise have been possible. But it was an arrangement that occurred only once every 176 years and would have to be taken advantage of by the late 1970s. NASA initially approved flybys of Jupiter and Saturn, and named the mission Voyager. Later they agreed to continue the funding to go on to Uranus and Neptune.

Two things change during a gravity-assist maneuver: the spacecraft's speed and direction. If the spacecraft approaches from behind, gravity will not only accelerate the craft in the direction of the planet's revolution around the sun, but it will also pull the craft in arc around the planet. If the spacecraft flies in front of the planet, gravity will slow down the probe.



Astronomy: Terri Field

In 1989, Voyager 2 flew by Neptune to complete its "Grand Tour" of the solar system, fully vindicating the mathematical expectations of twenty years before.

SWING LESSONS

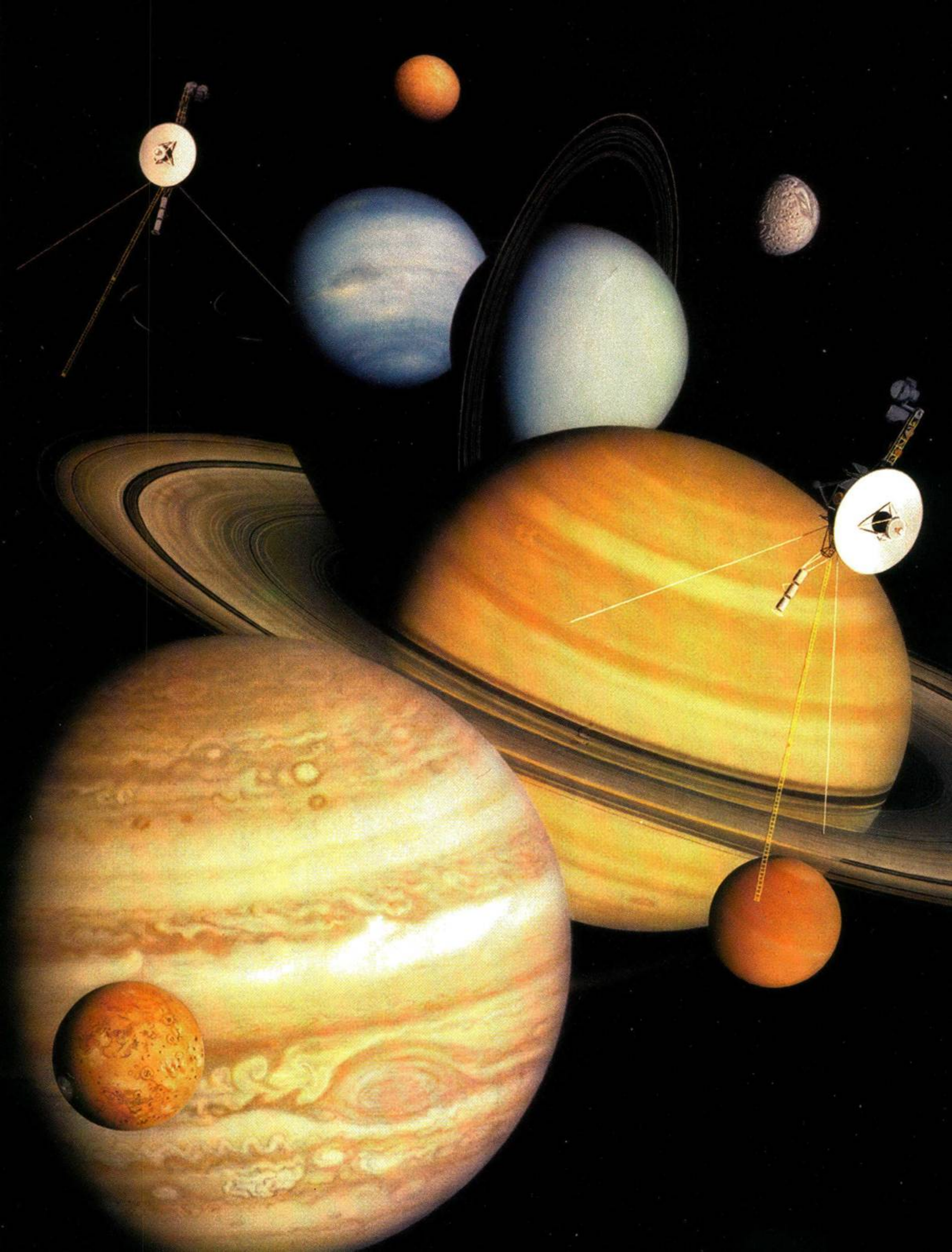
With the successful swingbys of Mariner 10, Voyager, and other spacecrafts, gravity assists gained validation. Trajectory designers began planning long, winding paths around planets to change the speed and direction of the vehicle. The routes added millions of miles to a craft's path, but in the end saved lots of rocket fuel — and consequently, money. In the case of Cassini, for example, engineers have designed a path that will take the probe a billion miles out of its way. But the gravity assists along the way will provide the energy equivalent to 75 tons of rocket fuel — a substantial boost for a ship that left Earth with only three tons.

"In the absence of a gravity assist, we would simply have to build a bigger rocket and launch it on a trajectory to go directly to the target," says Mitchell.

So how does a gravity assist work?

In simplest terms, a spacecraft exchanges momentum with a heavenly body to either speed up or slow down. Science fiction author Arthur C. Clarke offered a good analogy for this kind of exchange in momentum. He likened the maneuver to bouncing a ball off a moving wall. If you throw a ball at a stationary wall, the ball will rebound with about the same speed as it had before hitting the wall. Now imagine what happens if the wall is moving toward you. The ball rebounds with additional speed. The wall has transferred some of its momentum to the ball, causing it to speed up. And likewise, the ball has slowed the wall a negligible amount. The opposite occurs if the wall is moving away from you. A tossed ball rebounds with less speed. That's because the receding wall absorbs energy from the tossed ball,

Voyager flew by Jupiter, Saturn, Uranus, and Neptune to complete its "Grand Tour" of the solar system. Don Davis



causing it to slow down. And likewise, energy from the ball causes the wall to speed up a tiny amount.

On a flyby, spacecrafts and planets exchange momentum, too. To get an idea of what happens, imagine that you're riding in the front seat of a probe about to receive a gravity assist from Earth. From out in space, you see Earth in the distance and off to the left. It seems that you are on a course headed nowhere near the planet. But then the craft comes into Earth's sphere of influence, an imaginary realm encircling the planet where gravity has an affect. The force tugs on the vessel, causing it to diverge from its original course. At the same time, the spacecraft gains speed. As you veer closer to Earth, the force of gravity becomes stronger and the craft moves faster. At the same time, gravity is also altering the probe's trajectory, bringing it closer and closer to the planet. Over a span of time on closest approach, the change in velocity — a combination of speed and direction — sends the craft in a left turn around the planet. In addition, an exchange of momentum occurs between the craft and the planet, just as it gets exchanged between the ball and the moving wall. The spacecraft gains some of Earth's momentum while at the same time slowing down the planet a negligible amount.

According to Mitchell, Cassini will speed up by 11,000 miles per hour when it swings by Earth, and our planet will slow down by about 1 centimeter over about 2 million years. The curious thing is that from our planet's frame of reference, the space probe arrives and departs with exactly the same speed. Since we're moving too, we don't notice the momentum we add to the craft. But if we could stand on the sun and watch the event, we would see Cassini gain Earth's momentum and speed up.

FINDING A GOOD PARTNER

For any gravity assist, the determining factor in the magnitude of the speed change is the size of the planet and the approach speed of the spacecraft. The gravity from Jupiter will exert more force on a spacecraft than the gravity of our moon, for example. Another factor is the craft's flyby geometry. Objects that pass behind the planet will become caught in the planet's forward momentum and gain speed. But those that pass in front of the planet will get tugged in the opposite direction and slow down.

As a result, trajectory designers can vary the flyby geometry to produce a combination of maneuvers involving a change in velocity. They must also consider the geometry of the path with regard to the planet — don't hit the rings! These parameters are tied together, so often the planners have to balance the desired results against the necessary consequences. The number of variables have made many missions possible. The finest example is Galileo's tour of the jovian moons. About every two months beginning in December 1995, the probe made a close flyby of Ganymede, Callisto, or Europa, and it will be approaching Io again late this year. Flyby distances at each moon ranged from 120 miles to several thousand miles, and each encounter resulted in a new direction and speed.

The price paid for gravity assists is usually mission complexity. They often require a sequence of planet encounters in order to build up adequate velocity for reaching the outer solar system, for changing orbital planes enough to reach comets and asteroids, and for getting closer to the sun. In the future, advanced high-efficiency engines may allow interplanetary missions to proceed directly to their targets. But for now, engineers continue to develop new and more-sophisticated gravity-assist missions.

One of them involves the Japanese spacecraft, the Nozomi Mars probe. It pioneered a gravity-assist trajectory using a highly elliptical Earth orbit and a series of lunar flybys. These allowed scientists a much bigger launch window in which to put the probe on course for Mars. In a few years, the same path will be used by a whole new class of small Ariane-V-launched Mars hitchhiker payloads. Nozomi, meanwhile, botched its rocket burn last December 20 and used up so much maneuvering fuel that its normal Mars orbital mission became impossible. However, by using a series of gravity assists from Mars and two from Earth (becoming the first space vehicle to make the Earth-Mars-Earth round-trip), it will be able to creep up on Mars much more gently in about four years to complete its mission. In the future, space hotels — which will consist of the heaviest life-support components needed for the months-long voyages — may repeatedly traverse the very same Earth-Mars route to carry people back and forth between the planets.

The entire idea of gravity assist missions is a wonderful example of how, while we still can't break or even bend the laws of gravity, we can invent clever new ways to exploit those laws, to find the loopholes and send our spacecraft — and eventually ourselves — along those hitherto uncharted paths. ◼

James Oberg is a veteran space flight expert and writer residing in Texas, who has been contributing to Astronomy *since 1974. His home page is www.jamesoberg.com.*

The HGS-1 satellite was the first commercially owned craft to receive a gravity assist — in this case, from the moon.

Hughes Space and Communications Company

DANCING WITH THE MOON

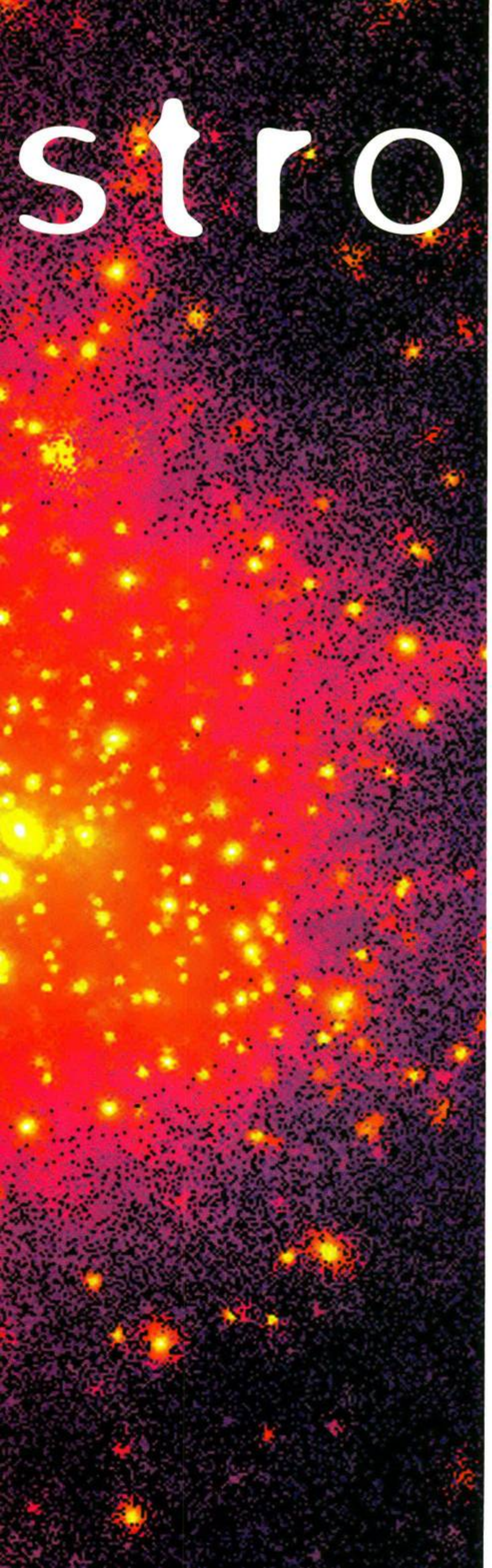
Forty years after Earth's governments began sending probes to the moon, a U.S. corporation followed the path blazed by the Luniks, Pioneers, Apollos, and Zonds. In May of last year, Hughes Space and Communications Company salvaged a failed satellite orbit and made history with the first commercial mission to the moon.

Hughes had built the HGS-1 satellite for Asiasat, an Asian telecommunications consortium. During liftoff, the launch rocket malfunctioned, placing the craft in an unusable, highly elliptical orbit over Earth. There was a small amount of reserve fuel left, but it was not enough to make the necessary orbital change.

The company was about to write off the satellite as a loss. But orbital planners at Hughes refused to give up. They drew up plans to send the satellite toward the moon, where gravity could help reposition the craft's orbit. On May 13, 1998, the satellite made its first swingby of the moon. Lunar gravity twisted the craft's orbital plane and raised it up to the desired level. A second swingby on June 6 improved the craft's orbit to near perfection.

"The lunar recovery mission team did an outstanding job," says the company's president, Ronald Swanson. "It really validates the viability of this technique for future missions." *— J. O.*

Virtual A



stronomy

Astronomers are using supercomputers to model the mergers of stars, the motions of gas in the sun, and even the evolution of the universe.

by Adam Frank

There's baseball and then there's the World Series. There's soccer and then there's the World Cup. In astronomy there are problems and then there are the Grand Challenges.

It's no secret that astrophysics is hard. With mounds of data to sort through and hairy equations to solve, astronomers face issues that are anything but trivial. Some problems, however, are so frighteningly complex they are in a league of their own, problems such as the motions of gas inside stars or the evolution of the universe.

These are the Grand Challenge problems — time-honored riddles in astrophysics that are so difficult to solve they can only be approached with the most powerful theoretical tools available — massively parallel supercomputers (which have very large numbers of processors). Traditional problems require solutions. Grand Challenge problems demand simulations, the wholesale recreation of the universe in virtual space.

What makes an astrophysical problem worthy of the label Grand Challenge? How do astronomers go about solving them with supercomputers? How can they tell if the answers provided by the computer simulations are correct? Pursuing these questions takes you into the very heart of the new science known as computational astrophysics.

Taking the Challenge

The term "Grand Challenge" refers specifically to a series of programs funded by the National Science Foundation and NASA. These agencies award scientists special Grand Challenge grants so they can advance the state of the art in computational astrophysics.

Computational astrophysicists begin with the same basic equations of physics used by traditional "pencil and paper" theorists. But the equations describing many problems in astrophysics are so complex they are unsolvable by pencil and paper methods. Instead of manipulating these equations manually, computational theorists let a machine do the work. By repetitively performing millions of simple calculations, a computer can solve these monster equations one tiny step at a time.

A T-shirt from a Grateful Dead concert? No, it's actually a frame from a computer animation that simulates the evolution of a galaxy cluster. When problems such as this become too complex to calculate by pencil and paper, astrophysicists turn to silicon intelligence. Greg Bryan and Mike Norman (National Center for Supercomputing Applications)

Mike Norman

"In the end, the simulations have to match what astronomers observe," says Mike Norman.

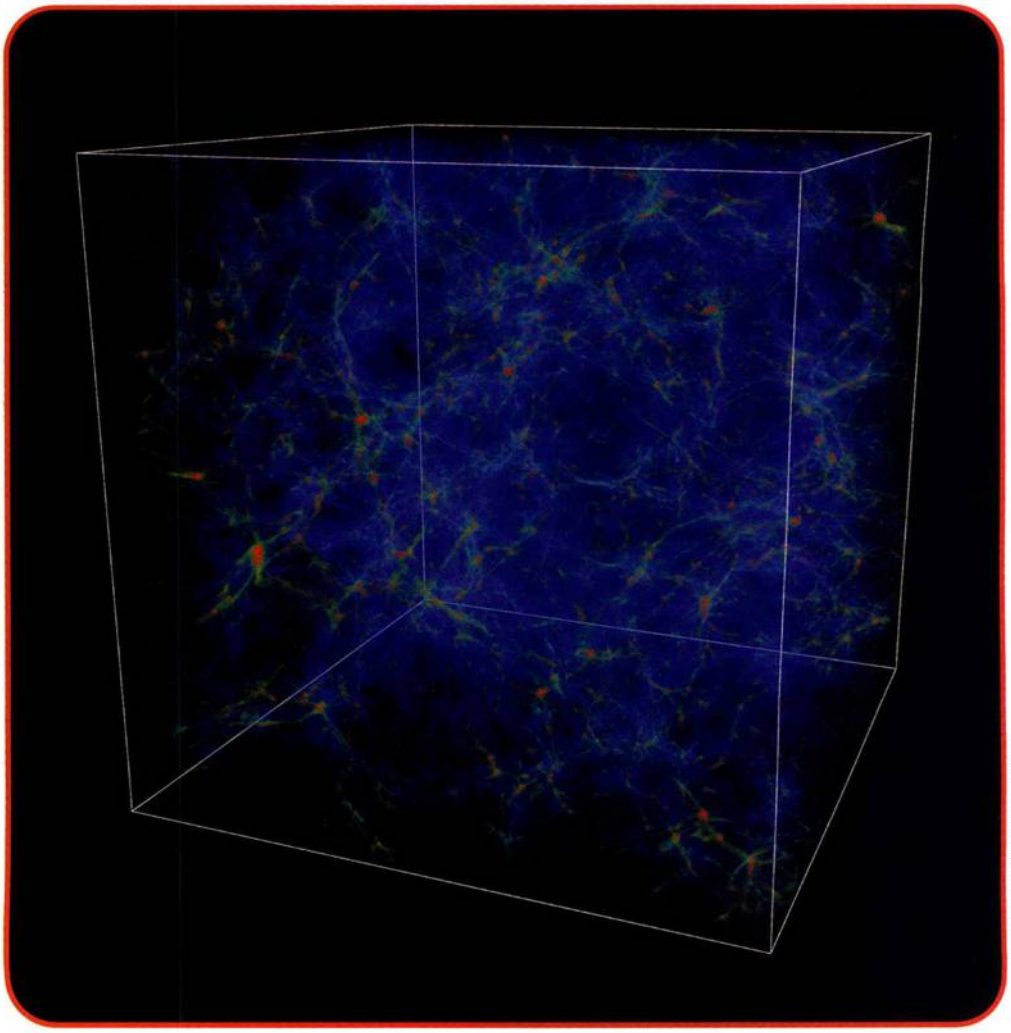
Imagine you are studying the evolution of a galaxy. A computer can provide approximate solutions to equations describing the motions of all the galaxy's billions of stars if you simply allow it to push those equations forward in time by just a little bit, maybe by only a few thousand years. By repeating this process, the computer can build up a solution for an entire galaxy over billions of "simulated" years. Like an animated Disney movie in which many frames are created to depict a complete story, the computer's repetitive calculations, called numerical simulations, allow astronomers to watch the evolution of a galaxy. Computational astrophysicists are essentially transforming their basic, but traditionally unsolvable, equations into animated movies.

An accurate simulation involves millions or even billions of calculations every second. With the rapid increase in computational speed and memory, desktop and even laptop computers are now capable of running sophisticated numerical simulations. Grand Challenge problems, however, require more computational horsepower than these machines can deliver. "A Grand Challenge problem means that you must simultaneously simulate the evolution of things that are small and things that are large, processes that happen very rapidly and processes that happen very slowly," says University of Illinois astrophysicist Mike Norman.

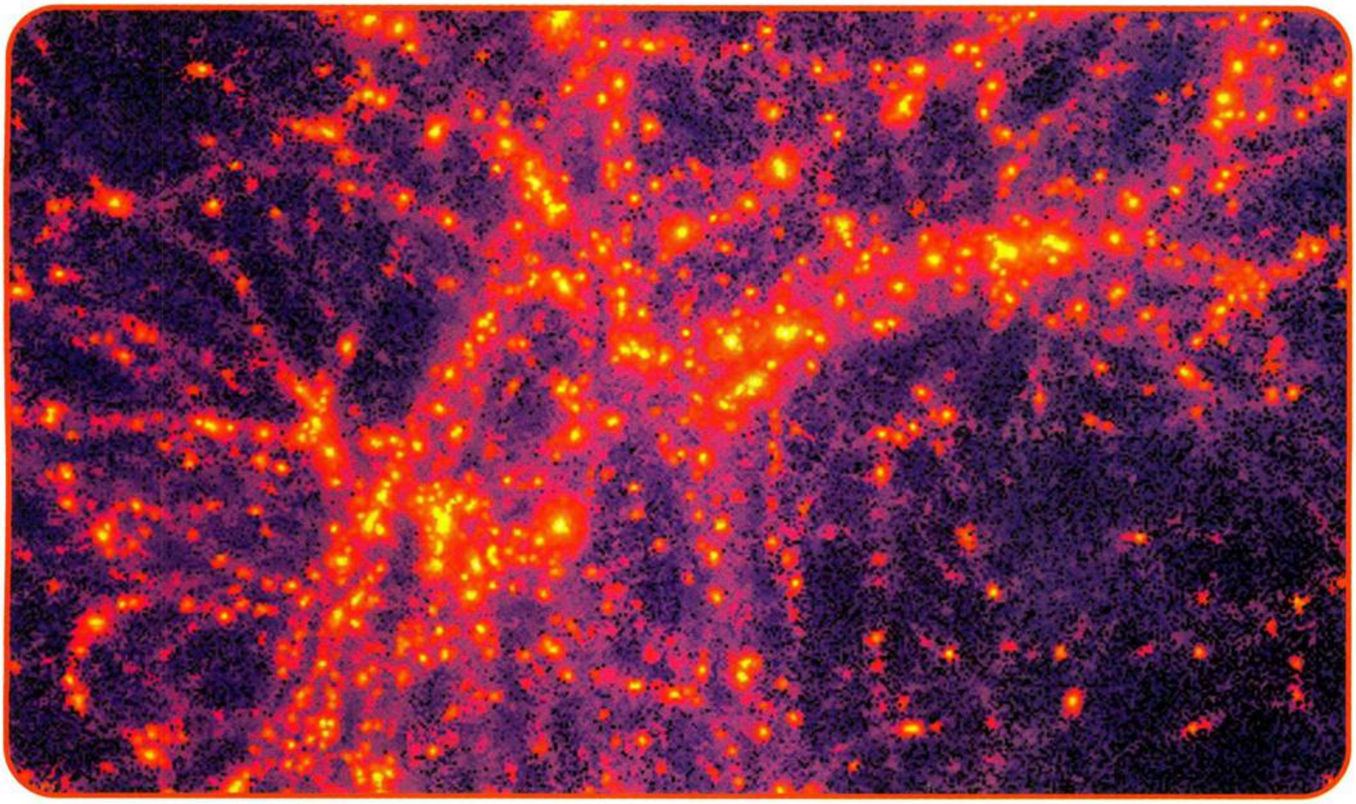
"Grand Challenge problems also involve lots of different kinds of physics," Norman continues, "and that really adds to the number of calculations that must be performed." A typical Grand Challenge problem will follow the motions of gases, the chemistry in the gases, the radiation in the gases, the influence of gravity, and the effects of high-energy particles. The list can be exhaustive and exhausting. The computer codes written to simulate these problems are often tens of thousands of lines long.

Taking on a Grand Challenge problem forces researchers to the latest incarnation of the supercomputer — massively parallel machines. The latest machines, which are the size of an automobile, can perform a trillion operations per second. Rather than a single

Using the power of supercomputers, scientists can simulate the entire universe in a small box.



Greg Bryan and Mike Norman (NCSA)



Greg Bryan and Mike Norman (NCSA)

microchip, a parallel computer can contain thousands of silicon brains. Each chip in a parallel computer gets a piece of the problem, perhaps a thousand stars in a simulated galaxy of 100 billion suns. The microchips work on the pieces separately and simultaneously. The different pieces of the problem must talk to one another, and that is where the "art" in "state of the art" comes into play. Working with these machines requires the skill of an orchestra conductor. Parallel computers only reach their maximum speed when all the microchips work in concert, calculating and then passing on information with perfect syncopation.

Cosmological Cube

As one of the pioneers of the current revolution in astrophysical simulation, Mike Norman knows a Grand Challenge problem when he sees it. In the early 1980s he carried out ground-breaking simulations of immense jets that shoot out of the cores of active galaxies at near light speed. Norman used the first true supercomputer, the famous Cray-1. These jets produce a complex, turbulent flow as they interact with their surrounding environment, taxing the capability of the Cray-1 to its limits.

Norman's current project is even more ambitious — simulating the entire universe. This endeavor, known as computational cosmology, seeks to answer one of the most fundamental questions in astronomy. If the Big Bang scattered material uniformly in all directions as theory predicts, why did the universe end up with large-scale structures — great walls of galaxy superclusters hundreds of millions of light-years long surrounding equally immense voids?

Using supercomputers to simulate a small section of the universe, Norman's group hopes to answer that question and track large-scale structures as they develop from one million years after the Big Bang all the way to the present. "This fulfills the definition of a Grand Challenge problem because it involves so many scales," explains Norman. The universe has many structural elements, such as stars, star-forming clouds, galaxies, clusters of galaxies, and superclusters of galaxies. Each element is radically different in size from the others. While star-forming clouds are tens to hundreds of light-years across, they are still minuscule compared to a galaxy supercluster. To accurately track the evolution of these different structures, Norman's simulations must capture the basic physics of how these objects formed, even though they formed at different size scales.

Norman's simulations begin in a virtual box about 500 million light-years on each side. "That's big enough to be representative of the basic physics occurring in the universe," says Norman. The box is subdivided into "computational cells." The computer tracks the evolution of gas motions at the center of each cell. Because Norman can't keep track of any structure smaller than a computational cell, the cells form the basic

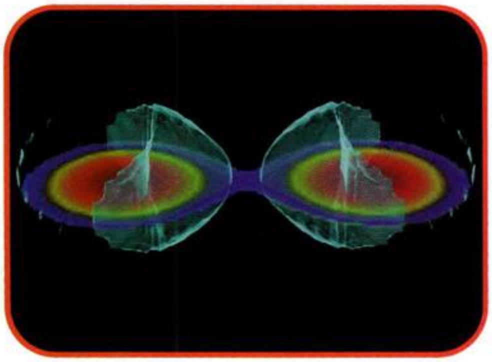
One of the Grand Challenges of computational astrophysics is to find out why galaxies arrange themselves into great walls, a simulation of which is shown in this University of Illinois animation.

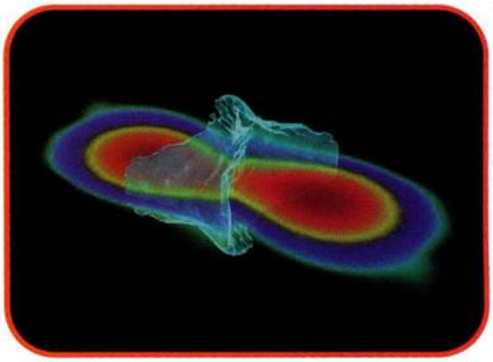
Nancy Rifkind

"Here we're seeing technology transfer from Hollywood to science," says Doug Swesty.

unit of the simulation. They're like pixels in a digital image, defining the simulation's all-important characteristic: resolution. To simulate a multi-scale problem requires lots and lots of cells, or high resolution. Norman's simulation uses more than 100 million cells. His most recent simulations use a new computational technology called "adaptive meshes," which means the cells move around and cluster wherever the action is. Regions where little is happening might be represented by a single large cell. With adaptive meshes, researchers get high resolution just where they need it.

"The need for high resolution," says Norman, "means supercomputers are limited not only by speed but also by memory." Computational cosmology simulations routinely generate hundreds or thousands of gigabytes (1 billion bytes) of data — that's equivalent to 1 million copies of *Astronomy* magazine for each simulation. Figuring out how to easily store, retrieve, and manipulate all that information is just one of the many technical hurdles Grand Challenge researchers must overcome. Problems of this complexity require that researchers such as Norman form teams of 20 to 30 scientists and computer programmers.





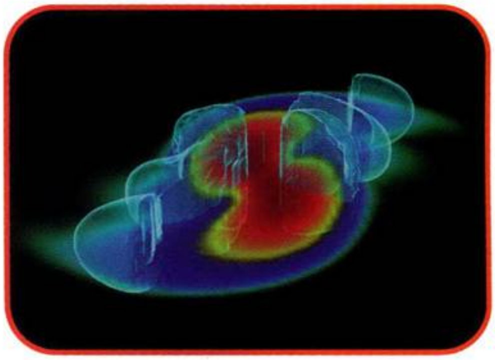
Norman's computational cosmology group has already enjoyed remarkable success. How does one define "success" in computational astrophysics? Just like traditional theoretical studies, the proof of the pudding is in the eating. "In the end, the simulations have to match what astronomers observe," says Norman. The team has simulated the formation of large- and small-scale structures, including details such as the existence of extremely hot x-ray emitting gas in galaxy clusters. After the x rays had been seen with a variety of satellites, Norman's group was able to show how the gas was heated from its own internal motions. As gas slops back and forth in a newly forming cluster, shock waves heat it to temperatures above 10 million degrees, all of which was neatly captured by the simulations.

This success has simply whetted the researchers' appetites. "Now we want to show how the first generation of stars was formed," says Norman. "We want to see structures created from the bottom up."

Gravity's Twins

Problems don't have to span millions of light-years to be worthy of the Grand Challenge label. Sometimes difficult problems come in small packages. Doug Swesty of the State University of New York at Stony Brook studies binary neutron stars, orbiting pairs of dead, city-sized, ultradense stars. As the neutron stars circle each other, they drive ripples — called gravitational waves — outward in the fabric of space and time. The energy carried away by gravitational waves comes at the expense of the orbit, so the neutron stars spiral inexorably closer together. Eventually they spiral in completely and merge in a cataclysm of heat and light. The process is sudden, extremely violent, and wickedly difficult to simulate.

The gravitational field surrounding a neutron star is so powerful that Newton's theory of gravity breaks down, so astrophysicists must turn to Einstein's general theory of relativity (which describes how matter, space, and time interact). While Einstein's equations are graceful and elegant in principle, they are mind-numbingly complicated to solve in practice. There are only a handful of simplistic situations where the equations become tractable enough to wrestle free a solution. Try solving the equations for a situation that involves two or more

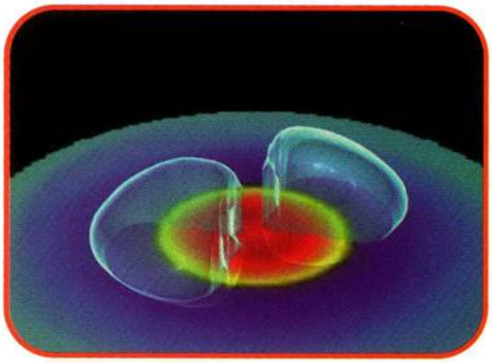


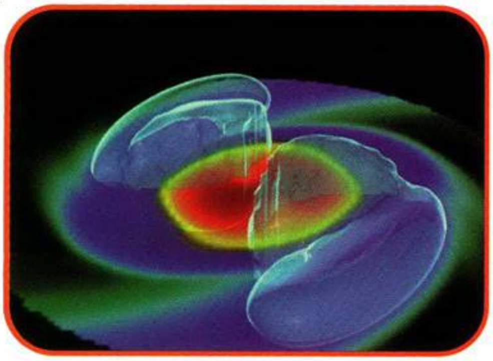
moving objects and you are left with a mathematical monster of staggering complexity.

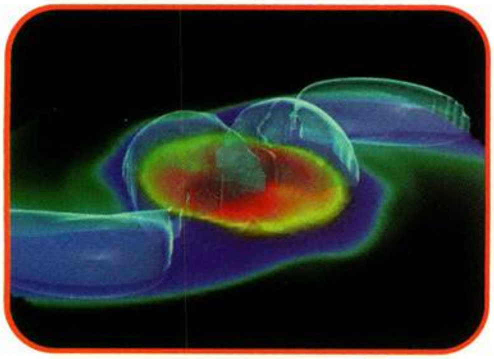
"There are 36 complex equations that have to be solved simultaneously if we want to follow the neutron stars as they spiral in toward each other," says Swesty. "We also need to hold on to about 110 different variables for the calculation; that's a lot." Swesty's simulation takes place in a box subdivided into 129 cells on a side. That's 129^3, or more than 2 million places where the computer has to solve the 36 equations and hold on to the 110 variables. These numbers translate into a grand headache in data manipulation and storage.

In spite of these difficulties, Swesty's group has risen to its Grand Challenge. In a recent series of simulations, Swesty and collaborators successfully tracked the "in-spiral" of two neutron stars all the way to merger. "We found all the action happens in the last three minutes," says Swesty. "That is when the intense gravitational wave radiation occurs and general relativity really comes into play."

As with Mike Norman's simulations, the ultimate test of Swesty's work will be the confrontation with real data. At the moment, scientists have yet to detect gravitational waves. But in 2001, the giant gravitational wave detector LIGO (Laser Interferometry Gravitational Wave Observatory) will set up shop in Washington state (a twin will start up about a year later in Louisiana). This "telescope" is actually composed of crossed laser beams that can detect gravitational waves. LIGO should be able to register the ripples coming from a neutron star merger, but researchers will have to know what to look for. That is where Swesty's work will be tested. "We are calculating what the gravity wave signature of a merger will look like," says Swesty, "so the LIGO people will know when they have found one."







A supercomputer simulates the violent merger of two neutron stars during the final 4 milliseconds. Gravitational waves are emitted from the light blue areas.

Doug Swesty, Dave Bock, Ed Wang, and Alan Calder

Some of the software Swesty uses was originally written to create the water creatures in the movie *The Abyss*. "Here we're seeing technology transfer from Hollywood to science," says Swesty.

Boiling the Stars

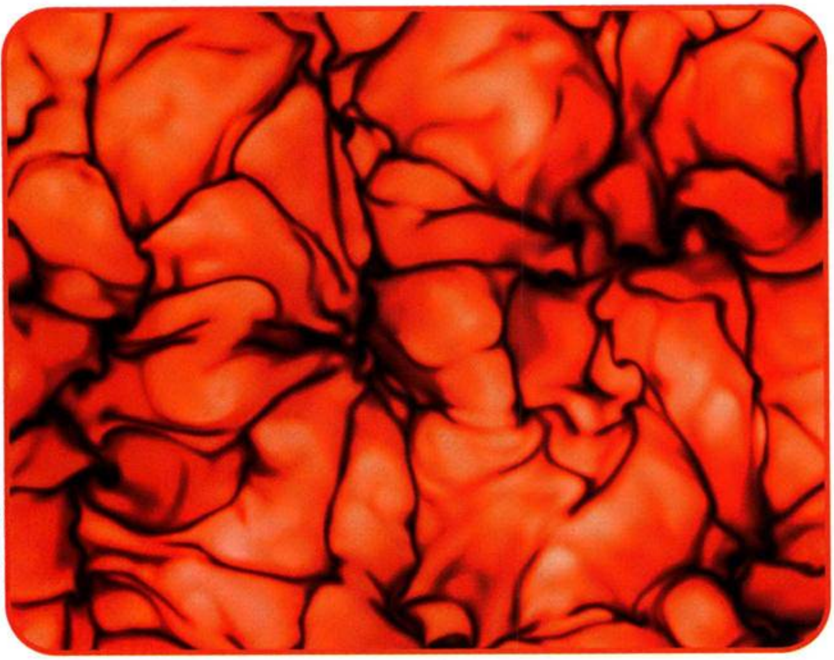
Grand Challenges occur close to home too. Compared with colliding neutron stars and the formation of galaxies, our sun might seem too familiar and ordinary to warrant much computational interest. Not so for supercomputer theorists. Hidden within all solar-type stars is a Grand Challenge problem 100,000 miles deep but as familiar as your kitchen stove.

Using massively parallel supercomputers, Andrea Malagoli of the University of Chicago studies the decades-old problem known as "stellar convection." When a fluid is heated from below, it becomes buoyant and rises. This happens in stars as fusion energy generated in the core heats the outer gaseous layers. The hot gas flows to the surface, cools, and then sinks downward, only to be reheated. "On your stove this motion is called boiling, in stars it's called convection," explains Malagoli. "Either way it's the same basic process."

By transporting heat from the lower depths of a star (about 100,000 miles down) to the surface, convection is a critical process in maintaining a star's equilibrium. "The problem," says Malagoli, "is that convection is so complicated that no one really understands how it works."

Andrea Malagoli

"The problem is that convection is so complicated that no one really understands how it works," says Andrea Malagoli.



Andrea Malagoli, Fausto Cattaneo, and Anshu Dubey (University of Chicago)

Above: The surface of the sun as simulated by a computer at the University of Chicago. Dark areas correspond to cold (downward flowing) gas. Below right: A computer captures the turbulent convection motion in a solar-type star.

Like boiling water, stellar convection is a turbulent process. It's a mess of tangled, tumbling gas motions. Understanding turbulence is so hard that it has become one of the Holy Grails of physics. Simulating turbulence is just as difficult. "The problem is all the size scales involved. You have to simulate an impossible range of sizes," explains Malagoli. To fully capture all the rolling motions in stellar convection, Malagoli's team has to simulate flows that change across both thousands of miles and inches. "We will never have that kind of resolution," says Malagoli, "but there is a lot we can do with the massively parallel computers."

To track the turbulent boiling motions in a star such as the sun, Malagoli's simulations break a small piece of a stellar interior into 26 million cells. What separates Malagoli's Grand Challenge from Swesty's or Norman's is that there's no definitive end to these kinds of calculations. "Stars just go on convecting," says Malagoli, "so we have to just cook our simulations until they reach some kind of steady state. We let the computer bubble away until the convection looks the same from one time to the next." That constitutes a computational expense endeavor. If one of Malagoli's simulations were run on a PC, it would take more than two centuries to complete. It takes his machine about a week.

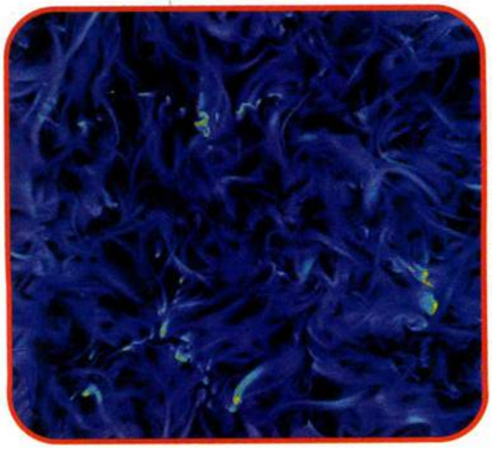
Unlike boiling water, the gas in solar-type stars is threaded by magnetic fields, which greatly complicates Malagoli's task. As the fields are swept along with the boiling stellar gas, they're pulled and stretched, becoming strong enough to provide a feedback on the convection. The fields change the flow and the flow changes the fields. "It's *very* complicated," says Malagoli.

In spite of the difficulties, Malagoli and his team have already gained substantial insights into at least one star, our sun. Their most recent simulations reveal how magnetic fields can get pooled into the convection pattern's downdrafts. Inside these downward moving columns, the field builds up to levels far more intense than scientists thought possible. "Everyone knows that sunspots are regions of intense magnetic fields," says Malagoli. "But most people think that magnetic fields are absent in regions between sunspots." Malagoli's calculations may force that attitude to change by demonstrating that strong fields can form on size scales too small to be currently observed. Like a time machine, Malagoli's simulations are looking into the future, predicting what the next generation of solar telescopes will see.

From Newton to Apples

Making contact with observations in a new and profound way is the ultimate goal of computational astrophysics. Though traditional theoretical methods cannot and should not be superseded, each of the examples above demonstrates that simulations can approach reality in ways not possible with the classic tools developed over the centuries. "In the past," Mike Norman muses, "simulations were simply inspirational. They gave you reason to look deeper, but they didn't have the same level of complexity as the observations. The physics was too simplified and the scales were all wrong. It was all apples and oranges. Now, with the new generation of computational tools," he says with excitement, "we can finally begin comparing apples with apples."

University of Rochester astrophysicist Adam Frank won an annual science writing award from the Solar Physics Division of the American Astronomical Society for his previous article for Astronomy, *"Blowin' in the Solar Wind" (October 1998 issue).*



Andrea Malagoli, Fausto Cattaneo, and Anshu Dubey

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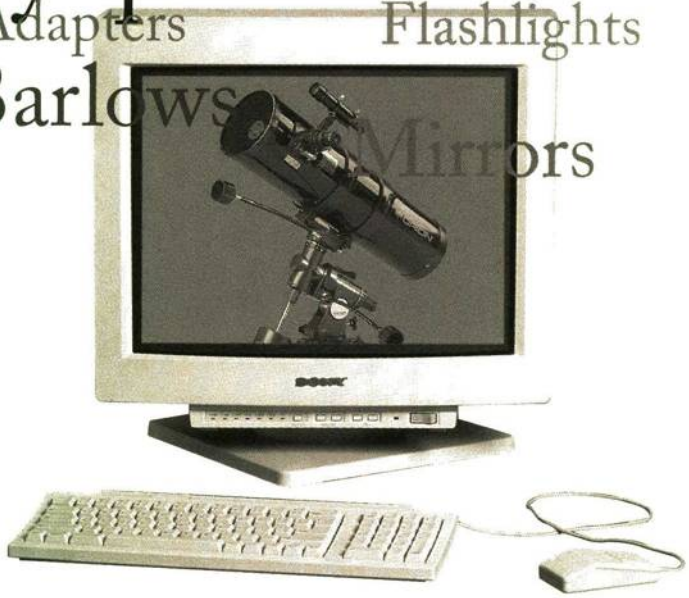

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THE SKY SHOW

The inner planets skirt the horizon as the sun gets eclipsed and Earth passes through Comet Swift-Tuttle's dusty wake. by Martin Ratcliffe and Alister Ling

▶ Warm weather and dark skies combine to make for pleasant observing conditions this month. Begin with **Venus** and **Mars**, which dominate the evening sky. Catch Venus early, as it dramatically falls from view. The planet sits just 8° above the horizon at sunset on August 1 and makes a rapid exit only to reappear in the morning sky at month's end. By August 11, Venus sets with the sun. Inferior conjunction occurs on August 20.

Highly skilled observers using telescopes can track Venus throughout this period. While the planet slides just 8° below the sun during its conjunction, try to catch its slim crescent moving from one side of Venus to the other.

In the first few days of August, Venus is almost 1' across and displays a phase that is illuminated by less than 10 percent on its western edge. On August 20, a thin sliver of the northern hemisphere will shine. By August 31, Venus is climbing rapidly in the early morning sky, but this time the eastern hemisphere is illuminated. Viewing this effect requires great care and a large telescope. Observers must not allow the sun to enter the telescope's field of view.

Low in the south at sunset, the bright star Antares shines at the heart of Scorpius the Scorpion. This fine constellation sits on the western side of the broadest and richest region of the Milky Way.

During the time of Confucius, the Chinese called the area "Ta Who," The Great Fire, which is also a primeval Chinese name for Antares.

The Arabians, who knew the star as "Al Akrab," were one of several groups that saw the stars of Libra as part of the Scorpion. These stars represented the animal's huge claws.

Antares, a red supergiant, shines at magnitude 0.96. The star is so large that if Antares were placed in the sun's position, its outer atmosphere would almost reach to the

Those fortunate enough to be living in the northeastern section of North America will see the sunrise in partial eclipse.

Diego Meozzi

AUGUST 1999

3 The moon passes 4° south of Jupiter, 10 P.M. EDT

4 Last quarter moon is at 1:27 P.M. EDT
The moon passes 3° south of Saturn, 8 P.M. EDT

6 The moon passes 0.8° north of Aldebaran, noon EDT

7 Uranus is at opposition, 3 P.M. EDT
The moon is at perigee (227,860 miles from Earth), 7:36 P.M. EDT

9 The moon passes 1.2° north of Mercury, 11 P.M. EDT

10 Venus passes 8° south of Regulus, noon EDT

11 New moon is at 7:08 A.M. EDT; total solar eclipse (page 84)

13 Perseid meteor shower peaks (page 68)

14 Mercury is at greatest western elongation (19°), 10 A.M. EDT (page 71)

18 The moon passes 7° north of Mars, 8 A.M. EDT
First quarter moon is at 9:47 P.M. EDT

19 The moon is at apogee (251,197 miles from Earth), 7:27 P.M. EDT

20 Venus is in inferior conjunction, 8 A.M. EDT

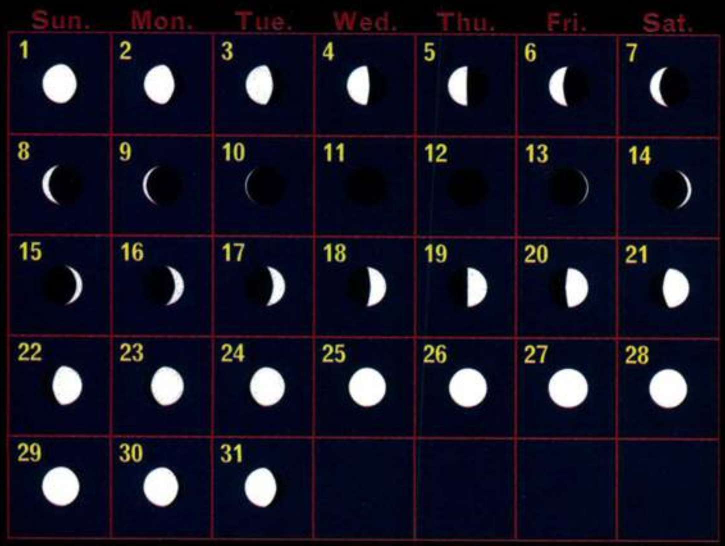
24 The moon passes 0.7° north of Neptune, 10 A.M. EDT

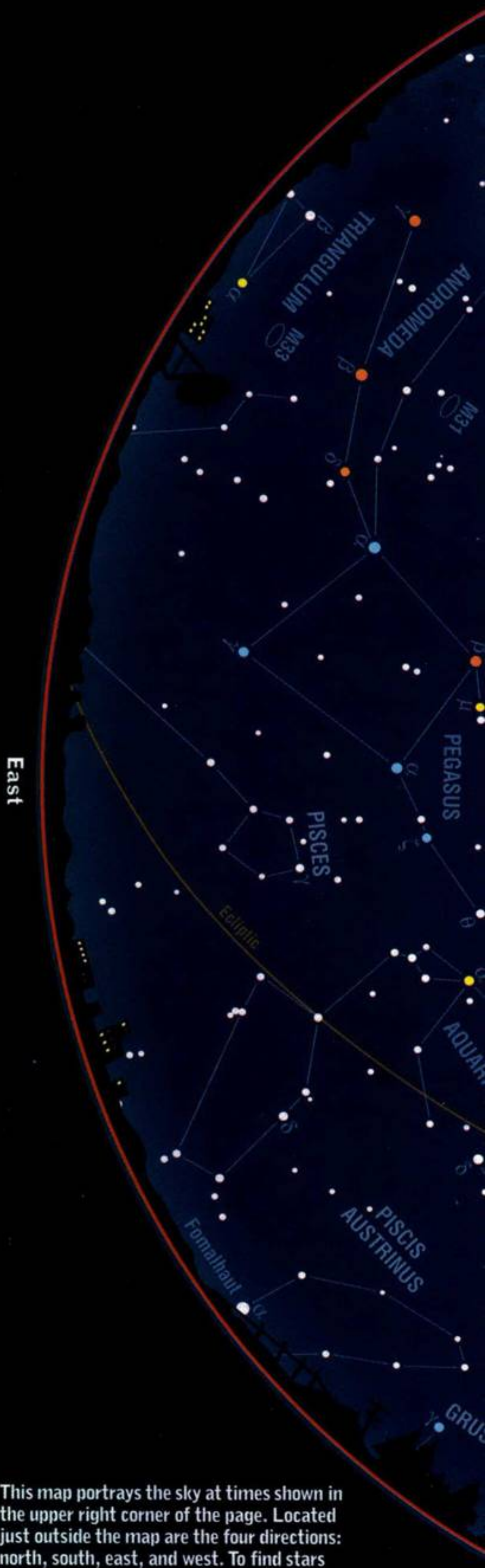
25 Jupiter is stationary, 8 A.M. EDT
The moon passes 0.6° north of Uranus, 9 A.M. EDT

26 Mercury passes 10° north of Venus, 8 A.M. EDT
Full moon is at 7:48 P.M. EDT

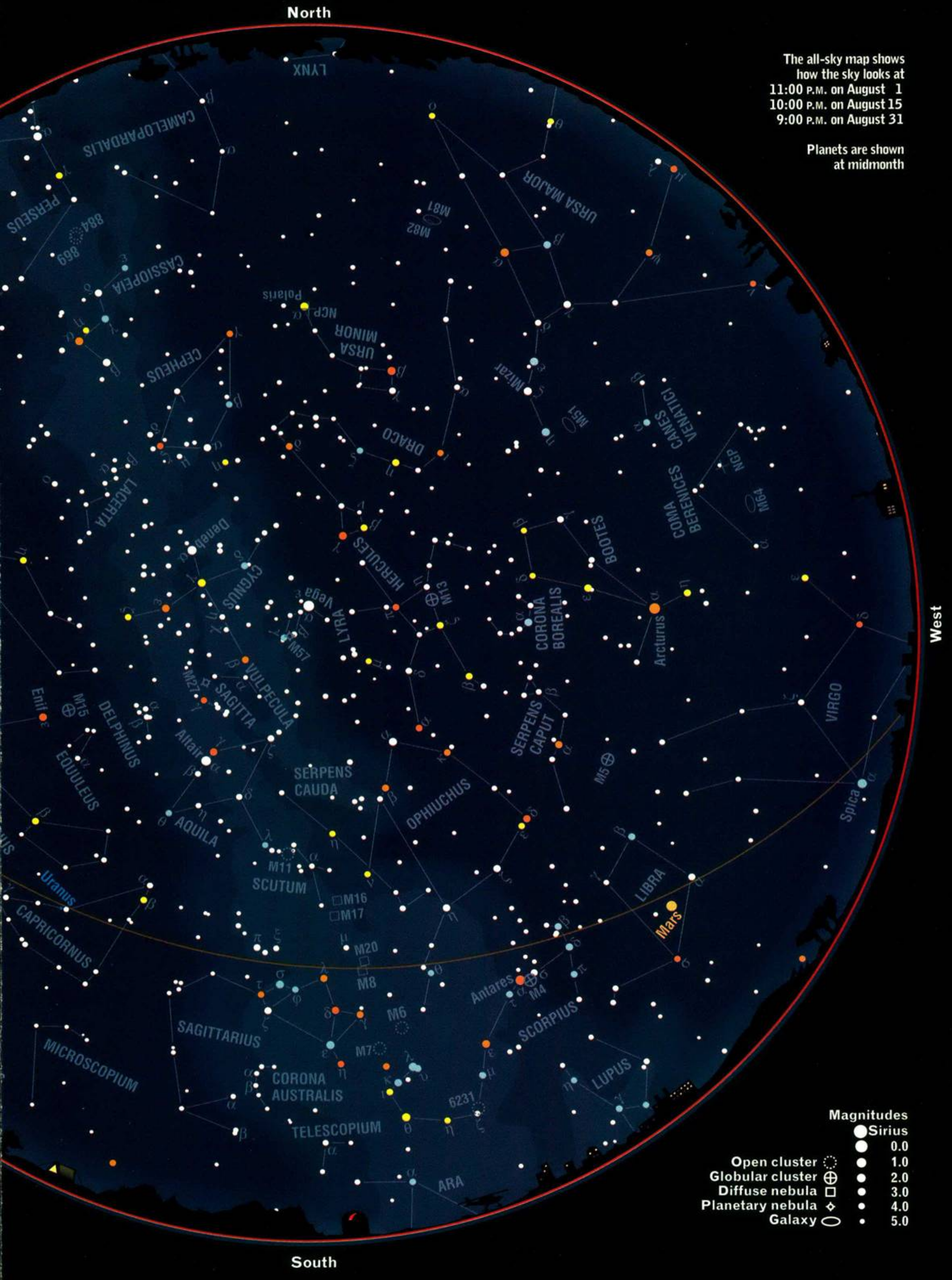
30 Saturn is stationary, noon EDT

31 The moon passes 4° south of Jupiter, 5 A.M. EDT





This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

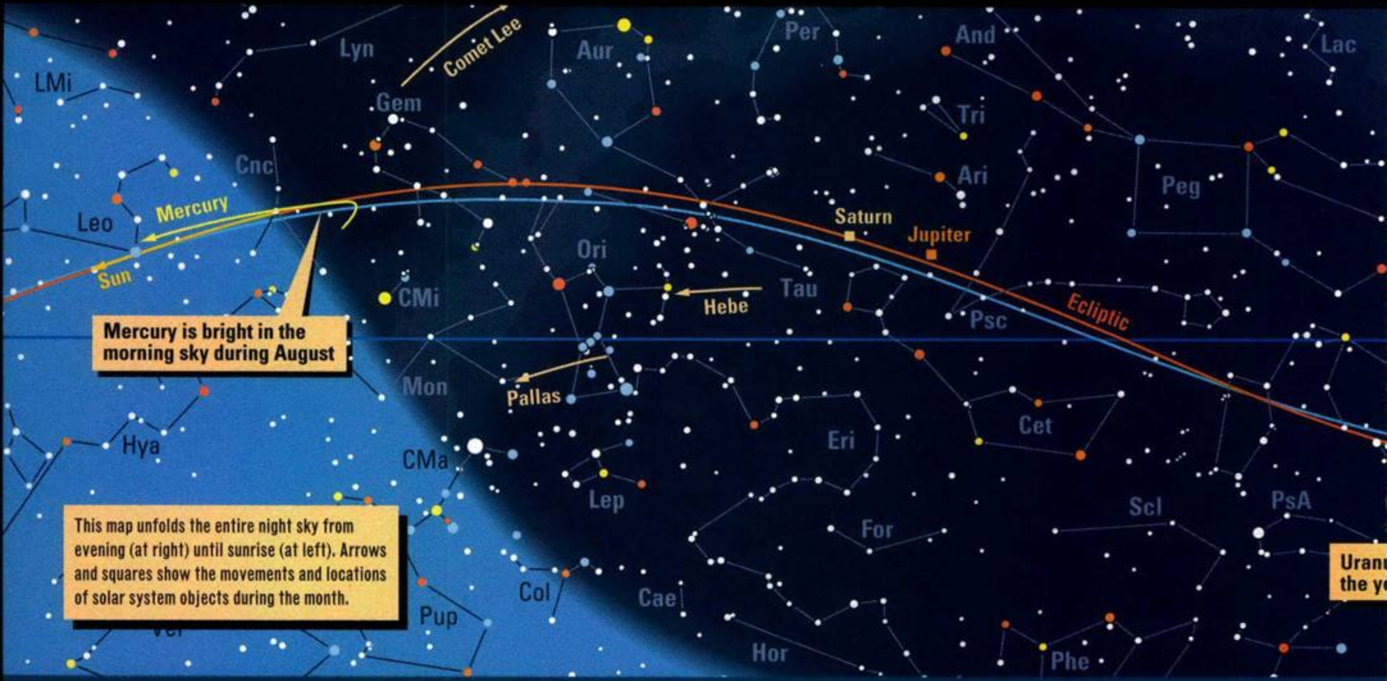


North
LYNX
CAMELOPARDALIS
PERSEUS
884
869
CASSIOPEIA
URSA MAJOR
M81
M82
Polaris
NCP
URSA MINOR
CEPHEUS
Mizar
M51
CANES VENATICI
DRACO
NGP
M64
COMA BERENICES
LACERTA
Deneb
CYGNUS
HERCULES
M13
BOOTES
Vega
LYRA
M57
CORONA BOREALIS
Arcturus
West
Enif
M15
DELPHINUS
M27
SAGITTA
VULPECULA
SERPENS CAPUT
VIRGO
EQUULEUS
Altair
SERPENS CAUDA
M5
OPHIUCHUS
Spica
AQUILA
M11
SCUTUM
Uranus
M16
M17
LIBRA
Mars
CAPRICORNUS
M20
M8
Antares
M4
M6
SAGITTARIUS
SCORPIUS
MICROSCOPIUM
M7
CORONA AUSTRALIS
LUPUS
6231
TELESCOPIUM
ARA
South
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

The all-sky map shows
how the sky looks at
11:00 P.M. on August 1
10:00 P.M. on August 15
9:00 P.M. on August 31

Planets are shown
at midmonth

THE PATH OF THE PLANETS

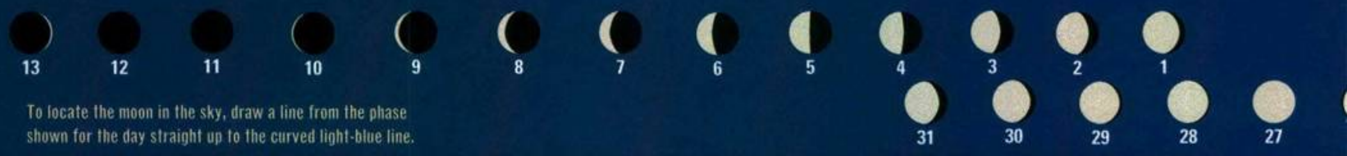


Lyn
Comet Lee
Aur
Per
And
Lac
LMi
Gem
Tri
Cnc
Ari
Peg
Leo
Mercury
Saturn
Jupiter
Sun
Ori
Tau
CMi
Hebe
Psc
Ecliptic
Mon
Pallas
Hya
Eri
Cet
CMa
Lep
Scl
PsA
For
Col
Cae
Pup
Vel
Hor
Phe

Mercury is bright in the morning sky during August

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.

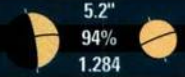
Uranu
the ye

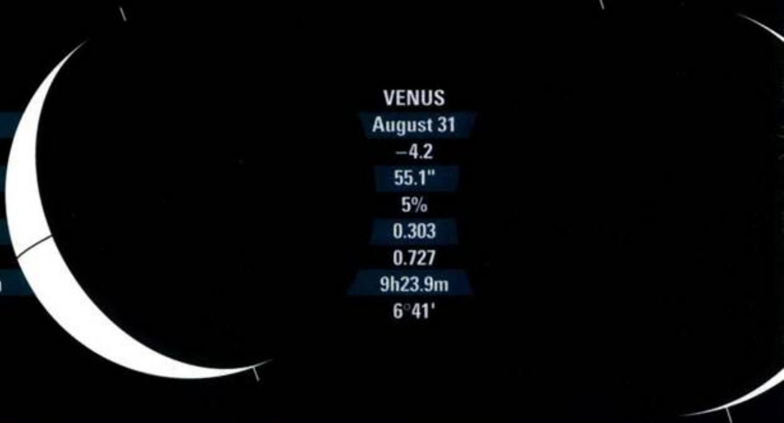


13
12
11
10
9
8
7
6
5
4
3
2
1
31
30
29
28
27

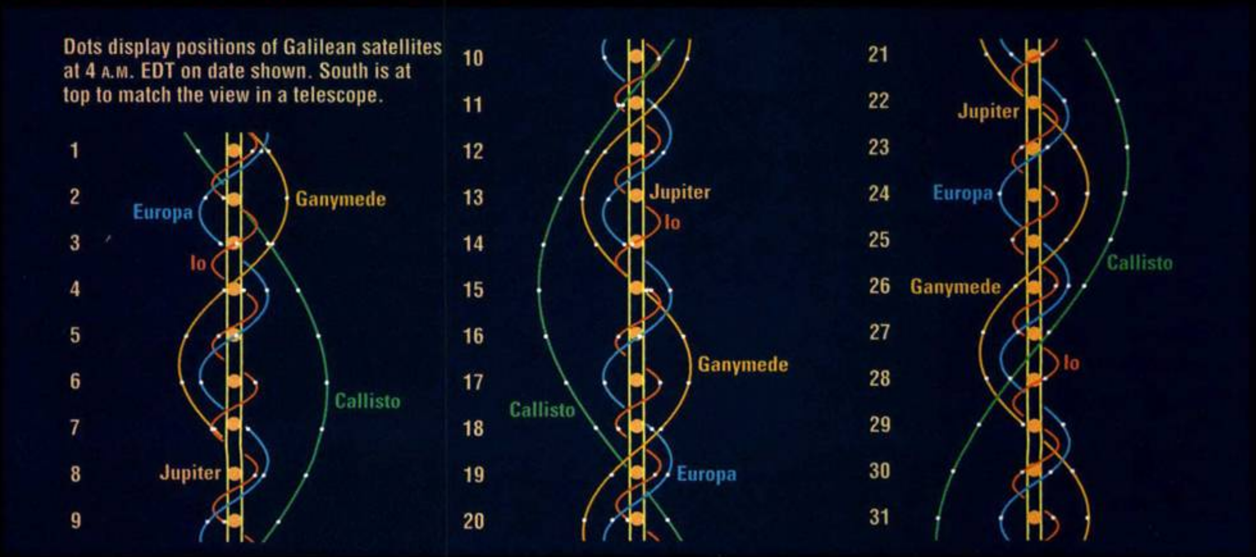
To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

PLANETS	MERCURY	MERCURY	VENUS	VENUS
Date	August 15	August 31	August 1	August 31
Magnitude	0.0	–1.4	–4.4	–4.2
Angular Size	7.4"	5.2"	48.9"	55.1"
Illumination	43%	94%	11%	5%
Distance (AU) from Earth	0.910	1.284	0.341	0.303
Distance (AU) from Sun	0.330	0.323	0.728	0.727
Right Ascension (2000.0)	8h20.1m	10h06.1m	10h20.8m	9h23.9m
Declination (2000.0)	18°29'	13°29'	5°21'	6°41'

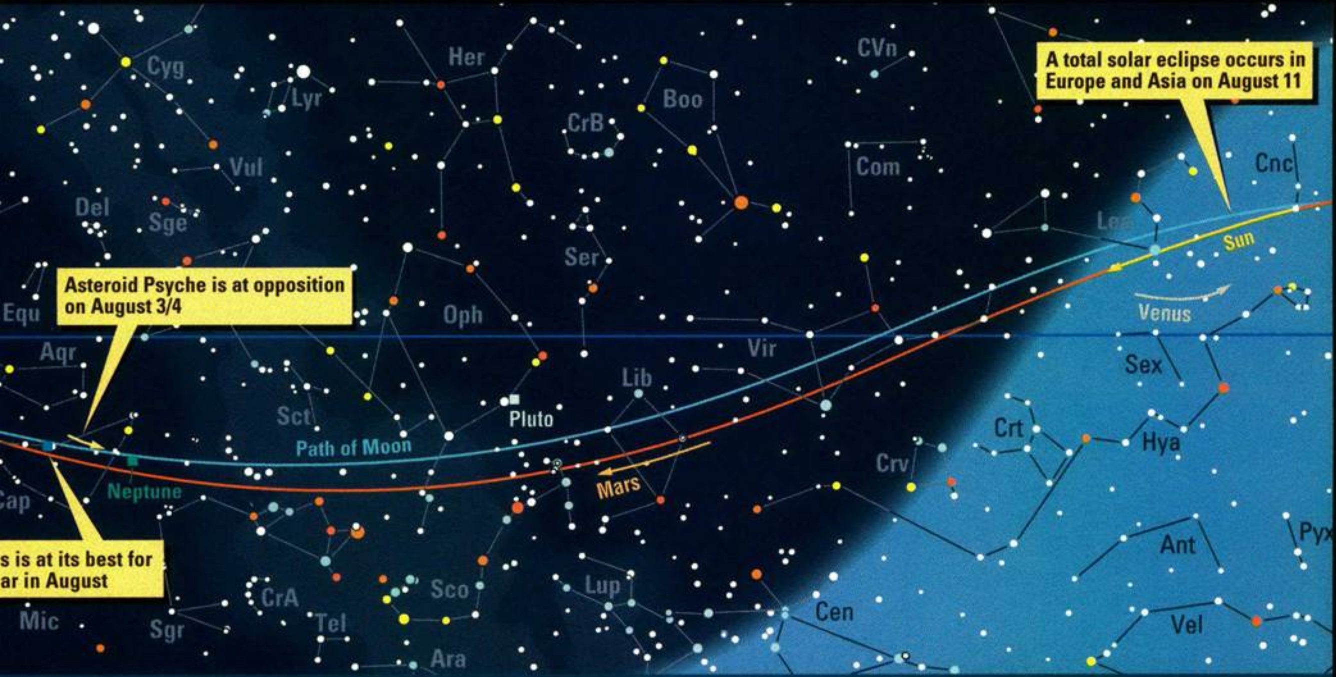




JUPITER'S MOONS



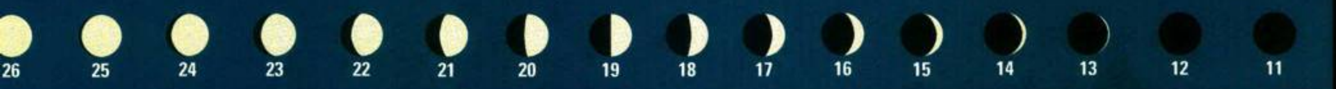
Dots display positions of Galilean satellites at 4 A.M. EDT on date shown. South is at top to match the view in a telescope.


Cyg
Lyr
Her
CVn
Boo
CrB
Vul
Com
Cnc
Del
Sge
Leo
Ser
Sun
Equ
Oph
Venus
Aqr
Vir
Sex
Lib
Sct
Pluto
Path of Moon
Crt
Hya
Crv
Neptune
Mars
Cap
Pyx
Ant
CrA
Sco
Lup
Cen
Mic
Sgr
Tel
Ara
Vel

A total solar eclipse occurs in Europe and Asia on August 11

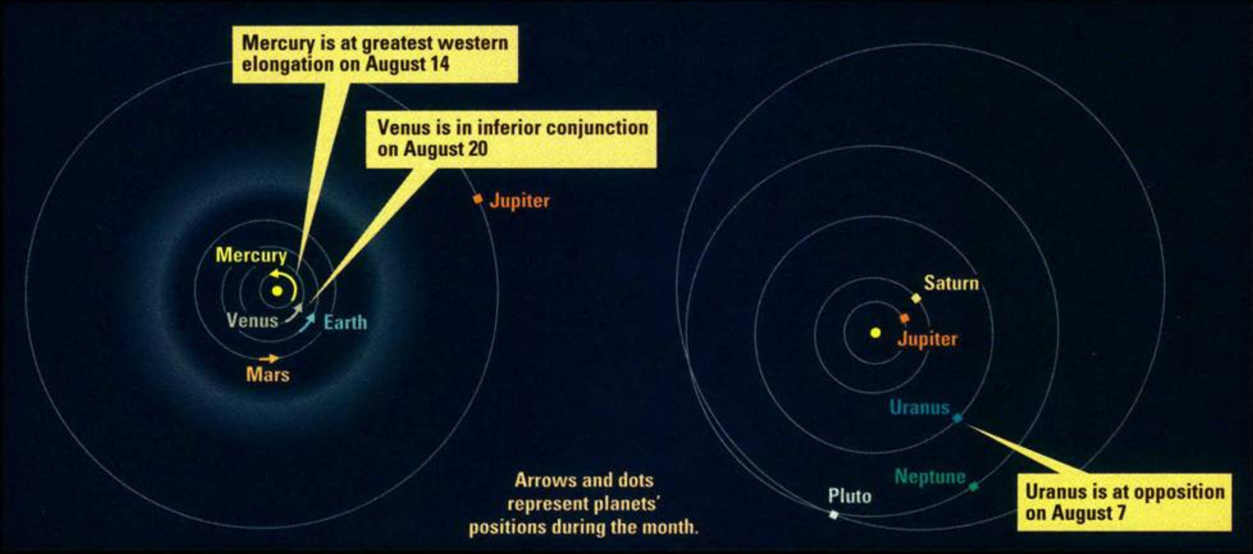
Asteroid Psyche is at opposition on August 3/4

s is at its best for
ar in August


26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11

MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
August 15	August 15	August 15	August 15	August 15	August 15
0.2	−2.6	0.2	5.7	7.8	13.8
8.6"	43.2"	18.3"	3.7"	2.3"	0.1"
86%	99%	100%	100%	100%	100%
1.089	4.562	9.075	18.905	29.168	29.894
1.449	4.953	9.215	19.910	30.125	30.183
15h03.5m	2h12.1m	3h00.9m	21h08.9m	20h18.7m	16h31.4m
−19°03'	11°50'	14°36'	−17°09'	−19°21'	−10°16'

THE PLANETS IN THEIR ORBITS


Jupiter
Mercury
Venus
Earth
Mars
Saturn
Jupiter
Uranus
Neptune
Pluto

Mercury is at greatest western elongation on August 14

Venus is in inferior conjunction on August 20

Uranus is at opposition on August 7

Arrows and dots represent planets' positions during the month.

FIRST VIEWS: Globular Star Clusters: Mind Opener, Eye Openers

Eighty years ago astronomers believed the solar system was at the center of the Milky Way Galaxy. In 1920, however, Harvard astronomer Harlow Shapley used globular clusters to put us in our place. Astronomers realized we live in the galactic suburbs.

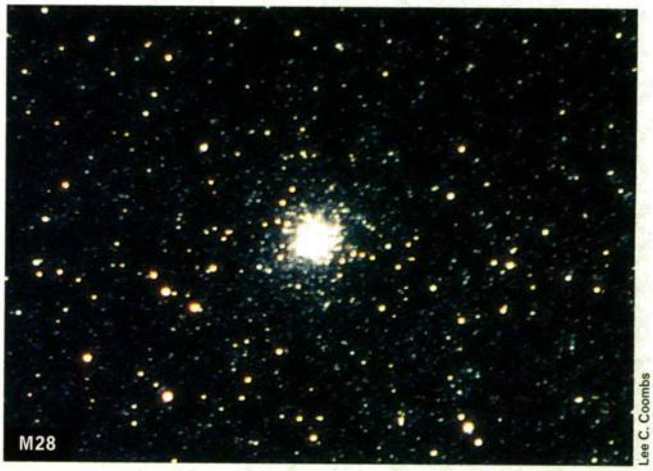
Shapley's reasoning went like this: Picture yourself in a large room full of people. You are trying to find the middle of the room. If you assume that everybody is the same size, then you can tell how far away they are by how tall they appear to be. If you are standing at the edge of the room, most of the people are visible with a glance. The view is an apparent blend of bigger and smaller people, depending on their distance from you. Globular star clusters follow this pattern. The pattern would be different if we were at the center of the galaxy. Of course, the assumption that all globular clusters are the same size is a problem, but the method works well enough to put the wrong theory to rest. Where is the center of the galaxy? In the direction of the constellation Sagittarius the Archer, which looks like a Teapot. One-quarter of the best globular clusters visible from mid-northern latitudes lie in this bright constellation.

French astronomer Charles Messier, a comet hunter in the late 1700s, cataloged the best globular clusters because they could easily be mistaken for comets in the crude telescopes of the day. We know these objects by their Messier or "M" numbers. M22 is one of the most impressive clusters in the sky. Its brightest stars glow at 11th magnitude, so a 3-inch scope under dark skies can turn this hazy blob into a myriad of stars. Messier's old telescope and eyepieces did not have the quality to yield this resolution. To him they appeared fuzzy and cometlike. From a city backyard, you'll need a much bigger scope to view M22 in its glory.

M28 is a snap to find. It's the 24th brightest globular in the sky and in smaller telescopes appears to be a fuzzball. Use high power on steady nights to reslove the cluster into its component stars. The brightest of these stars shines at 12th magnitude. M55 is a tad harder to reach but well worth the effort. Its 11th-magnitude stars pop out everywhere across its disk.

Because globular clusters are compact, you can really boost your telescope's power to get a better look at them. The overall view gets a little dimmer as magnification increases, so shield your eyes with your hands or put a dark cloth over your head.

The next three clusters lie just north of the Teapot's base. They each have nearly the same brightness and size, and therefore they appear much the same at low power. However, at higher magnifications, from a dark-sky site, the differences are striking. M69's brightest stars peak at 13th magnitude, well within the reach of an 8-inch telescope. M70's stars peak at 14th magnitude, and M54's just reach the crest at 15th magnitude. Contrast the views of globulars whose stars can be resolved to those that appear granulated and the ones that remain fuzzy.


M28

Lee C. Coombs

M55

Lee C. Coombs

M22

Robert W. Provin and Brad D. Wallis

orbit of Jupiter. For all its size (more than 400 times the diameter of the sun), Antares is only 30 times more massive than our star.

Antares means the "equivalent" or "rival" of Mars. This title becomes relevant in August as Mars lies less than 30° to the west of Antares. As the month progresses, the planet slowly approaches its rival. Antares gets its color from its temperature of 3300 K. The red surface of Mars is the result of a fine, rusty sand that covers the planet.

Mars crosses Libra the Balance and fades by 0.3 magnitude to below magnitude 0 by month's end. Features on Mars are becoming harder to see as the ruddy disk shrinks to 8' in diameter. The Red Planet's next opposition will occur in June 2001.

Comet Tempel 2 lies in the same region of sky. This short-period comet, in a 5.5-year orbit, reaches perihelion on September 8. During August, the comet is visible in binoculars from a dark observing site as it wanders among the southern section of Ophiuchus.

Early in the month, the dim fuzzball competes for attention with the globular cluster M9. The similarity in appearance may cause some confusion, but Tempel 2 should be fainter and will move from night to night with respect to the stars.

Later in the evening **Uranus** can be found in Capricornus the Sea Goat. The planet's 5.7 magnitude is technically visible to the naked eye under ideal conditions, but most observers will need binoculars to identify it.

Discovered in 1781 by Sir William Herschel, Uranus reaches opposition

Mars: Never Say Die

Maurizio Di Sciullo

If you've been hooked on Mars since its wonderful show this past spring, you're in luck. The Red Planet is still worth observing.

Most planets sink rapidly behind the sun in the west because Earth's swift orbital motion passes them. Mars is close enough to Earth's orbit that it can almost keep up.

The important thing to keep in mind is that Mars is only 20° above the horizon as it gets dark, so it is significantly affected by turbulent air currents. Start observing Mars as early as possible — even before sunset if you have setting circles or a computerized telescope.

Mars is nearing its early winter season, so you should get a chance to watch its north polar cap grow.

The western sky is fairly empty at dusk at mid-month. Only Mars and Arcturus punctuate the deepening twilight. They are similar in color and brightness, but by Labor Day, Mars will be 0.3 magnitude fainter.

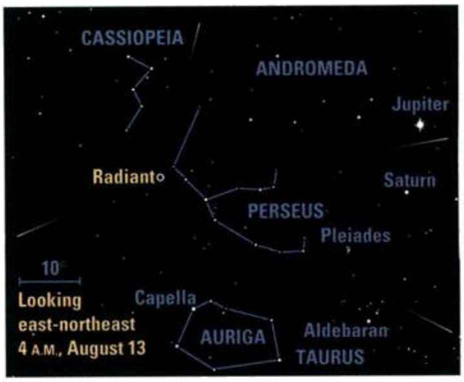
Perseids for the Populace

If you're keen on meteors, we've just hit the high season. One of the year's best showers peaks during the afternoon and through the night of August 12/13. November's Leonids and December's Geminids may boast more bright fireballs, but seeing them requires braving cold temperatures.

Grab a lawn chair or an air mattress and a blanket to ward of the night's chill. Then gather the family together with a few good friends for a night of oohs and aahs. This is the perfect opportunity to introduce newcomers to the night sky. Bring along binoculars for general stargazing and to look at luminescent trains from the brightest meteors.

The Perseids typically provide 80 meteors per hour under ideal viewing conditions. However, this can vary. In some years, the Perseids have provided only a trickle of "shooting stars," while other years have brought a magnificent display of 200 meteors per hour.

Moonlight often interferes with observing the Perseids. This year, new moon occurs just before the peak. We'll have dark skies all night. It's tempting to simply watch from the backyard, but if you live in a medium-size city, more than two-thirds of the meteors will be lost to skyglow. Take the family out to a dark-sky site. The kids will enjoy the mini-adventure of driving out of town and staying up late.



Looking east-northeast 4 A.M., August 13

All illustrations/*Astronomy*: Terri Field

The peak is slated for Thursday, August 12 at 6 P.M. EST (closer to local midnight if you're in Europe). A secondary peak is predicted to occur around 1 A.M. August 13, but these times could easily be off by a few hours.

Generally speaking, the wee hours of the morning are favored because that's when Earth travels head on through the particle stream. Because the meteors peak on the afternoon of August 12, the preceding morning may offer a pretty good show. Check out the North American Meteor Network website at web.infoave.net/~meteorobs for more information.

on August 7. By the end of August, Uranus lies a mere one-eighth of a degree from magnitude 4.0 Theta (θ) Capricorni. It remains in the same binocular field with Theta all month, making the planet's identification easy.

Beyond Uranus, the far-flung planet **Neptune** shines two magnitudes fainter. Neptune reached opposition at the end of July and can be found very near the magnitude 5.3 star Sigma (σ) Capricorni. A telescope will show little of its 2" diameter globe, though its distinct bluish color should stand out.

Eclipse watchers across the world descend on Europe this month for the last eclipse of the millennium. On August 11, the moon's pencil-thin shadow will streak across Earth along a line from England, through Europe (Stuttgart and Munich in Germany and Bucharest in Romania), and Turkey and Iran, and on to India. Those lucky enough to be in the path of totality will see the entire sun blocked from view. Such an event reveals the delicate, elusive, and beautiful outer atmosphere of the sun, the corona. For more information on this event, see "Euro Eclipse" on page 84.

A day or two after the eclipse, a nighttime spectacle returns. The Perseid meteor shower occurs under relatively ideal conditions. The moon is just past new for the night of maximum on August 12/13, giving meteor watchers dark skies all night. The typical rate is 80 meteors per hour with an average magnitude of 2.3, though most observers will be able to track 50 to 60 meteors per hour in dark skies. If the

Catch a Bright Satellite

Artificial satellites can be fun to watch. Sure, most astronomers curse them for brightening the sky. Even during the Perseid meteor shower maximum, satellites will still get the highest hourly count. Still, moving lights in the sky have attracted many to the hobby, simply because they offer the chance for a person to ask, "What is that?"

We see satellites in the evening or morning sky because they orbit high enough to still be in sunlight, though at ground level we're in darkness. As satellites orbit Earth, their bodies and solar panels reflect sunlight differently. This changes the object's brightness. Though the change is usually slow, sometimes it can be dramatic. A rapid increase in brightness is called a flare, and Iridium satellites offer the best show for this type of event.

Iridium communications satellites have three highly reflective antennae that can send sunlight toward Earth in a blazing flash — often their beacon is momentarily 40 times brighter than Venus. The upper right photo is of an Iridium flare.

Chris Dorreman

Some folks are simply content to spot the aging Russian Mir, the Hubble Space Telescope, or the new International Space Station and Space Shuttle (photo below) delivery missions. These satellites appear as bright as the brightest stars and move at a steady pace across the sky. Still other observers record the times of satellite flashes or watch the reflected sunlight from geostationary communications satellites.

Several free prediction programs are available via the Internet. They allow you to calculate the paths of satellites that will pass over your particular longitude and latitude. Start with the Visual Satellite Observer's Home Page at www2.satellite.eu.org/sat/vsohp/satintro.html.

H.J.P. Arnold

weather doesn't cooperate for the peak, remember to also look a few days on either side of maximum. These nights offer a good number of meteors as well. Although meteors can appear from anywhere in the sky, the point in space from which the meteors appear to emanate (the radiant) lies within the constellation Perseus. The best place to look is roughly 50° away from the radiant. This is where the meteor trails are the longest.

Will the passage of the stream's parent comet, Swift-Tuttle in 1992, still have a positive effect on meteor rates? Perseid meteors are at their best in the early morning hours, when the radiant is high. Our view at that time is directly into the stream of meteoroids, the direction in which Earth is moving.

The morning hours also hold the two giant planets, **Jupiter** and **Saturn**. Both planets lie high in the southeast before dawn. Jupiter is two months away from opposition and brightens to magnitude –2.7 by August 31. You can find it rising over the eastern horizon about an hour before local midnight on August 1 and a few minutes earlier each subsequent night.

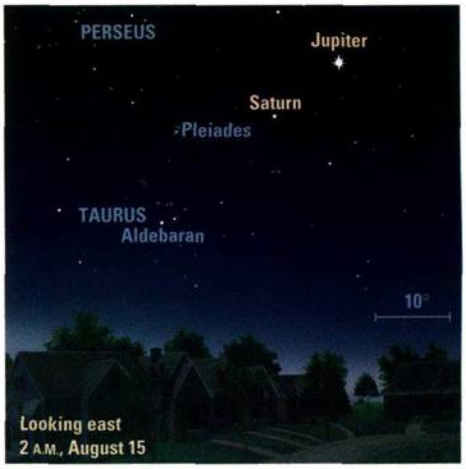
Rising about 40 minutes after Jupiter is the planet Saturn. Only 12° separate the two planets against the stars of Aries. Saturn is farther from the sun than Jupiter. Its fainter glow shines at magnitude 0.5. The planet would be even fainter were it not for its giant ring system currently tilted by 15° to our line of sight. At roughly 17" across, the planet's disk spans a mere one-third of Jupiter's giant orb. However, if you

Jupiter, Saturn, and the Late Night Band

Observers finally get their first telescopic view in months of two old favorites. If you're like most people, you will eagerly point your telescope toward Jupiter and Saturn to see a washed-out, blurry view as they sit just above the horizon. Staying up late, however, will allow you to get a really good view of the planets as they rise higher in the sky.

If you head to dark skies, look for the zodiacal light. This faintly glowing swath crosses the sky following the ecliptic. Microscopic dust grains in the plane of the solar system scatter sunlight back to Earth, creating the glow.

Observing the zodiacal light is sometimes tricky. You may not notice the glow until someone points it out, and then it's fairly straightforward to find.



John E. Cordiale

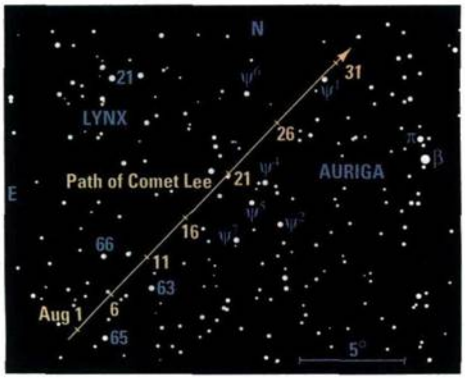
To spot the zodiacal light, look for a glowing cone rising from the horizon (see photo at left). Watch for the sky's background brightness to change as you slowly scan up from the horizon. You might see a brighter horizon haze followed by darkness, then a slightly brighter sky. This is the zodiacal light. The sky then begins to fade again as you look higher. You may have to block Jupiter's glow with your hand to avoid being dazzled.

Once you recognize the faint band that follows the ecliptic, you'll notice that Saturn clearly lies beneath it, as shown on the sky chart.

See a Brand-new Comet

On April 16, 1999, Steven Lee discovered a new comet at a star party near Mudgee, New South Wales, Australia. Orbital elements indicate that Comet C/1999 H1 Lee is a long period comet that will reach perihelion (closest point to the sun) on the farside of the sun on July 11.

Observers wishing to spot the icy interloper should look low in the northeastern predawn sky in the second week of August. As the month progresses, the comet will be gaining altitude but getting dimmer. On August 10, it will glow at magnitude 7.6. Five days later, on August 15, Comet Lee will shine at magnitude 7.8. By the end of the month it will have reached magnitude 8.2.



By September, Comet Lee will be a circumpolar object for most Northern Hemisphere observers. It will continue to dim, but binocular observers can spot it.

add the long axis of Saturn's rings, the planet reaches Jupiter's diameter of 42".

Small telescopes reveal the thin, dark rift in the ring system called the Cassini Division. The orbital period of particles in the region agrees with half the period of Saturn's tiny moon Mimas, one third of its moon Enceladus, and one-quarter the period of Tethys. This synchronicity of periods allows gravitational perturbations to keep the area relatively clear. Though many small particles reside here, this section of the ring is much thinner and so appears to be a gap. August is also the best time to see the shadow of Saturn's disk projected onto the face of the ring system. This gives Saturn a noticeable 3-D appearance.

Following the two giant planets in the sky, **Mercury** makes a brief appearance before dawn this month. On August 9, the waning crescent moon guides the way to Mercury located 8° to the lower left (east). The planet's greatest elongation west occurs five days later when it rises 90 minutes before the sun. Mercury continues to brighten through this date but dips quickly into the predawn glow, so catch a glimpse early.

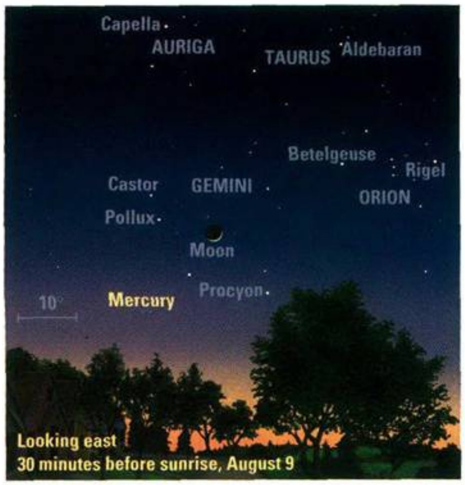
Mercury changes places with Venus, which appears in the morning sky at month's end. By August 31, Venus rises an hour before the sun and remains in the morning sky through the end of the year. **A**

Martin Ratcliffe is Director of Theaters at the Exploration Place in Wichita, Kansas. Alister Ling is a meteorologist working for Environment Canada in Alberta.

Have a Mercurial Morning

The innermost planet is more than swift. Its apparent behavior can sometimes seem bizarre. Newcomers to astronomy often find Uranus or even Neptune before they first see Mercury. Yet seasoned observers know if you plan ahead, Mercury is incredibly easy to spot.

Most planets brighten or fade as they orbit and the sun-Earth-planet angle changes. For Mercury, the change is large and swift. The planet is small (similar in size to the moon) and has no atmosphere, so it doesn't reflect a lot of sunlight (a factor of 6 less than cloudy Venus). Also, when Mercury approaches Earth and its apparent size grows, its phase thins to a crescent, making less of the planet visible from Earth. These circumstances combine to make Mercury a harder target.



Looking east
30 minutes before sunrise, August 9

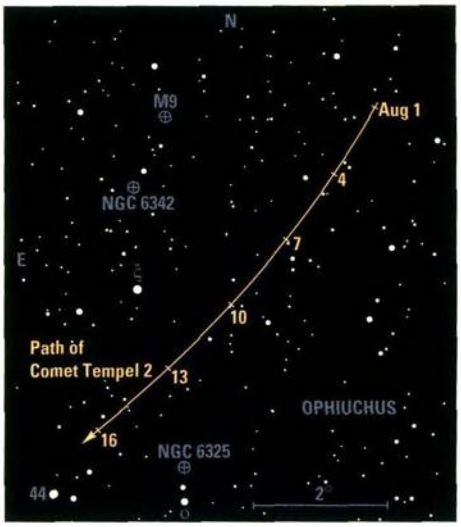
Start looking for Mercury on August 9 when a nearby crescent moon is readily visible. Begin looking about 50 minutes before sunrise. Scan the eastern horizon with binoculars. Follow the crescent moon's horns back toward the sun. There you'll find a feeble 1.0 magnitude blip. In only 5 days, when Mercury reaches its greatest distance from the sun, its magnitude is 0. On August 19, it's at magnitude –0.6, and by August 24, it reaches –1.0 magnitude. At the close of the month, Mercury is too close to the sun to be seen. Mercury can be spectacular one night and much tougher to see one week later.

Comet P/Tempel 2 and Charles Messier

Follow in the footsteps of French comet hunter Charles Messier this month, as Comet Tempel 2 cruises past a number of globular clusters, including a bright Messier object.

Because comets are diffuse, you'll want to have reasonably dark skies to get a good look at Tempel 2's 9th-magnitude glow and small tail. Make sure you head out during the first two weeks of the month because a waxing moon will brighten the skies during the latter half of August.

Tempel 2 begins the month 3° southeast of Eta (η) Ophiuchi (the leftmost of three bright stars in a line) and, coincidentally, 3° west of M9 (an 8th-magnitude globular cluster). On August 11, Tempel 2 will lie almost halfway between two globulars, roughly 2° on either side. Magnitude 9.8 NGC 6342 is to the north, and NGC 6325 at magnitude 10.6 is to the south. Their component stars are too faint to see except in large scopes.



Tempel 2 passes 0.5° (one moonwidth) away from the bright planetary nebula NGC 6369 on August 18, offering astroimagers an opportunity to catch the pair together. The moon itself will be too close for visual observers to get a decent look.

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By Philip S. Harrington

Here is the perfect reference for anyone, who owns a telescope or a pair of binoculars but doesn't know what to look for amid the constellations. It explains how to find double and multiple stars, variable stars, open and gobular clusters, nebulae, and galaxies — what you'll see when you do.Includes 36 full-page sky charts; equipment, books, and software suggestions; sketches of how deep-sky objects look through a small telescope; and more than 100 black & white photographs. 272 pages.

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LIFTOFF!

Watching a space shuttle launch is always a thrill.

by Djuna Ivereigh

Night settles over Cape Canaveral. But darkness is a losing battle at Kennedy Space Center's Launch Complex 39A. Forty searchlights converge on space shuttle Endeavour, then beam past her into the heavens where she is scheduled to ascend.

Six miles from the pad, I've convened with another 5,000 onlookers to witness Endeavour's imminent departure from Earth. By prior arrangement with NASA, we've gained access to a section of the Kennedy Space Center grounds normally closed to the public. Flashing precious car passes, we've been ushered past security checkpoints, then funneled onto the Astronaut Causeway, a narrow stretch of asphalt connecting Cape Canaveral to the Florida mainland. Here we have assembled from all walks of life, from all across the United States, and even from all over the world. Like modern-day pilgrims, we stand in masses around rental cars, camper vans, and RVs. Picnic dinners are served, kids squeal, grandparents let them get away with it. A thousand tripods point their cameras, camcorders, and unknown digital gadgets all in one direction. The air sparks with anticipation.

With binoculars, I peer out toward Endeavour. There it is, all right. The massive external fuel tank, spewing icy clouds of liquid hydrogen and oxygen, the paired solid rocket boosters (are those O-rings okay?), and the orbiter itself. I'd already been reprimanded for calling Endeavour a "shuttle." Regulars on site were quick to inform me that "shuttle" refers to the winged thing *plus* fuel tanks and boosters. The winged thing alone is more properly called an "orbiter." I learn from my embarrassment.

The sight of the launch pad, when you're there, is at once intimately familiar and totally new. Sure, I've seen lots of launches on TV — back in the days when space was just as newsworthy as the latest White House scandal. But this is different. I'm here and that shuttle is right there — about to go. This is *real.*

On brochures, ticket stubs, and recorded announcements, visitors to the Kennedy Space Center are often reminded that they are touring a real, working space facility — tours may be modified accordingly. I thought these messages were solely for the benefit of the Disney World crowd. An hour's drive can't possibly jolt Disneyites from that hypnotic trance that allows painless extraction of their money.

For me — well, frankly, I was a little overwhelmed by how real this place was. Just to think I was standing on the very ground from which so many fantastic journeys had begun, from which

A spectacular display of flame, smoke, and sound: Endeavour clears the tower during its January 22, 1998, launch.

NASA/KSC

Photos: NASA/KSC

Left: The calm before the storm: Hours before launch, Endeavour rests peacefully on its pad at Launch Complex 39A. Right: Controlled fury unleashed: Endeavour lights up the night sky.

even more fantastic journeys would launch us into the future — it was more of a rush than I'd bargained for. I felt as if some invisible thread connected this place to the cosmos — a thin, delicate thread that tugged with surprising force at all curious minds.

Back on Earth, here at the Astronaut Causeway, a voice bellows out over loudspeakers: "T-minus three hours and holding. The astronauts will now commence boarding."

Wait — I know that voice. It's that same smooth NASA voice that just as coolly reported on the first launch of Columbia and on the last launch of Challenger: Bruce Buckingham — a stranger, but a friend.

"Commander Terrence Wilcutt leads his crew of seven across the launch pad access arm onto Endeavour."

Cool NASA Voice echoes through the night. Searchlights blaze. I look around at my fellow space fans, each drawn by that same ineffable urge that had drawn me here. Nah, this isn't real. This is *Close Encounters: The Director's Cut.*

The astronauts safely boarded, carry-on stowed, and tray tables in the upright and locked position, Cool NASA Voice resumes the countdown. "T-minus three hours. And counting."

Joyce Schulz, a fellow space fan, now sighs and knots her hands, "Oh, I'm really feeling for Andy," she says.

She means Andrew Thomas, who will take this flight to join two cosmonauts for a four-and-a-half-month stay on Mir. As an engineer at Lockheed Martin in Houston, Joyce took part in the year-long astronaut training that preceded this mission.

"Andy was booted ahead six months for this flight," she continues. "Most of that time he spent in Russia, trying to learn the language and his way around the Mir mock-up. He really fought for that two-week leave of absence so he could get home for Christmas."

Wow. Christmas. Homesickness. That guy is human. They're all human. Seven humans locked in a tin can, about to ride a slow-burning bomb into the sky. This *is* real.

The clock counts down, and fast. Somehow, even mundane ground checks and computer diagnostics take on a palpable excitement. (Anyone check those O-rings?) Together, we space buffs ride out that hopeful, somewhat queasy feeling you get watching the clock tick down on the championship game while the home team defends a narrow lead. (C'mon guys, you're doing great. Just don't blow it. Not *now*.)

Then, at T-minus 20 minutes, during a scheduled hold in the countdown, something goes wrong. What, exactly, is not entirely clear.

Having forgotten my picnic dinner, I've found my way to the on-site snack bar. Sequestered in

BOOKING A LAUNCH

THE EASY WAY:

Call (407) 867-4636 or go to www-pao.ksc.nasa.gov/kscpao/schedule/schedule.htm for the latest launch schedule. Dial (407) 867-6000 for details on obtaining a car pass. Or, read up on all launch viewing details at www-pao.ksc.nasa.gov/kscpao/carpass/carpass.htm.

Ultimately, you will need to send a postcard (yes, postcards are preferred) to Kennedy Space Center requesting a pass several months in advance of the launch you would like to view. Address the card to: NASA-PA-PASS, Kennedy Space Center, FL 32899.

If possible, leave some flexibility in your travel plans after the scheduled launch. Delays are less common than they used to be, but NASA doesn't control the weather . . . at least not yet.

THE NOT-SO-EASY WAY:

You can buy a bus ticket to a prime viewing area by calling (407) 449-4444 or in person at the Kennedy Space Center, a week before a scheduled launch. The latter option is a little risky. Tickets sell out fast. To be safe, be ready to buy your ticket when the doors open at 9:00 A.M.

When on-site access is totally sold out, the Kennedy Space Center can also direct you to the best off-site viewing areas. Again, call (407) 867-6000, or check their website for details.

One of the best places to view a shuttle launch is along the side of U.S. Highway 1 in Titusville, about 10 miles from the pad. Even from this distance, you can easily see, hear, and feel the launch. Just make sure you park your car off the road.

WHILE AT KENNEDY SPACE CENTER:

The coolest place to catch up on technobabble before and during missions is at the easily overlooked Launch Status Center. It's that little white dome in the corner of the complex, near the Astronaut Memorial. Enthusiastic, well-informed interpreters monitor all developments over NASA TV, explaining things such as "specific impulse" and what the astronauts eat for breakfast. Try to stump them with really tough questions. I dare you.

Countdown status information is also available at (407) 867-2314.

IF YOU CAN'T BE THERE:

. . . but you have satellite TV reception, point your dish to NASA TV (GE-2, transponder 9C, 85 degrees West, vertical polarization). It's the next best thing.

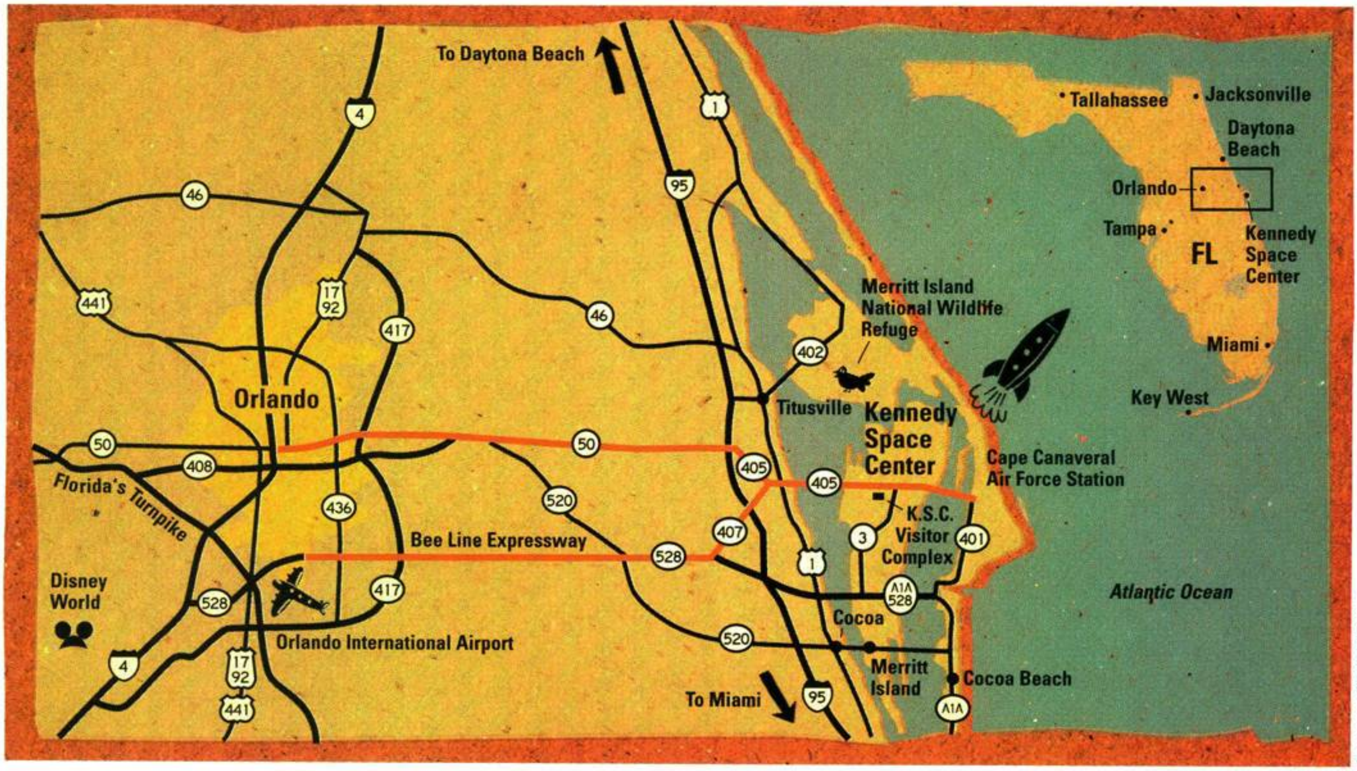
the NASA SnackMobile (the official catering truck of the space program), I rummage through sandwiches that make astronaut food sound appetizing. Outside, Cool NASA Voice reports: "Blah, blah, blah."

The crowd lets out a deflated moan. It's not like most of us really understand the Cool NASA Voice technobabble, but we know a problem when we hear one.

"Hey, no worries," says Carla, handing over my sandwich change. "I'm good luck. I've been out here for 16 launches. Every one I'm at goes off right on time."

"Wow, 16?" I ask. "Is it true what they say? No matter how many times you've seen the launch, it never gets old?"

Outside, Cool NASA Voice gives an update. We can't make out what he's saying, but he sounds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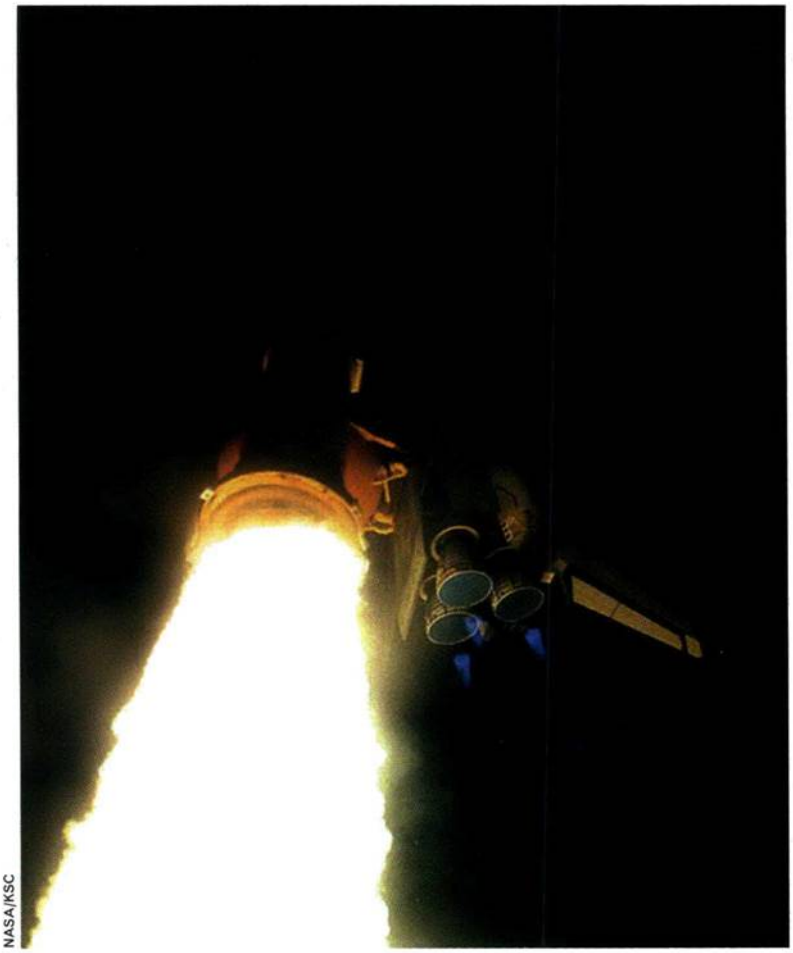
Astronomy: Elisabeth Rowan



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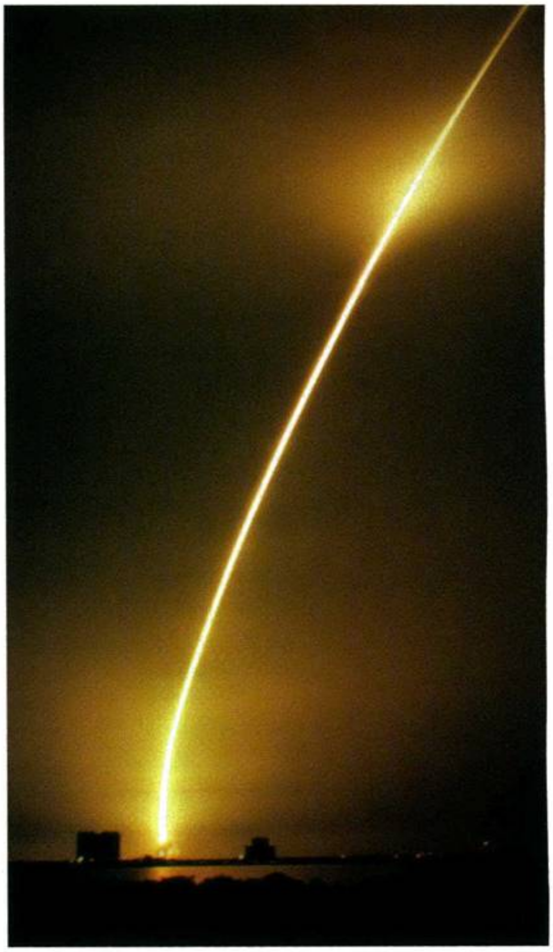


Gregory Gage

Left: Seven astronauts ride into space aboard Endeavour. Right: The launch of Challenger on August 30, 1983, provided this spectacular night-time display.

calm and collected. But then, doesn't he always? He is not to be trusted.

"T-minus 20 minutes and holding . . . possible delay . . . computer . . ."

I still don't know what he's talking about. But I stop to consider the computer system onboard Endeavour. It is, roughly, an 8086 processor, running DOS. I reflect back on the problems with our family's first PC — an 8086 processor, running DOS. I shudder.

To meet up with Mir, Endeavour must launch within an eight-minute window. If that window is missed, the launch is scrapped. Draining the external fuel tanks could be wrapped up by around 5:00 A.M. By noon tomorrow, the launch committee would decide to reinitiate the six-hour fueling process to prepare for the next launch window that night. Or decide it would be too risky due to weather.

The weather has been marginal all week. At this moment, rain is falling over most of central Florida. A patch of clear sky only recently opened over the cape. By tomorrow, conditions are likely to worsen, with lightning a strong possibility. Lightning and half-million-gallon fuel tanks aren't a good mix, despite the strong electrical shielding provided by the launch tower. If the shuttle launch were delayed for four days — a real possibility — it would be preempted by a scheduled military launch. Mission STS-89 would be postponed for nearly a month. NASA astronaut Dave Wolf, who's been on Mir since September, will have to wait another month to see his family and friends.

Time for somebody to hit that 8086 reset button.

". . . files reconciled . . . T-minus 20 minutes and counting." Whew! Those NASA boys do good. They know how to keep us on the edge of our

SCHEDULED SPACE SHUTTLE LAUNCHES

STS-99
September 16, 1999
8:47 A.M. EDT
Endeavour
Shuttle Radar
Topography Mission

STS-103
October 14, 1999
Discovery
Hubble Space Telescope
repair mission

STS-101
December 2, 1999
Atlantis
International Space
Station

STS-92
February 24, 2000
Discovery
International Space
Station

STS-97
March 23, 2000
Endeavour
International Space
Station

STS-98
April 20, 2000
Atlantis
International Space
Station

seats, too. Just watch *Apollo 13*. How much did I pay for *this* movie?

These last minutes now seem to be accelerating, rocketing off toward escape velocity.

T-7:30 — the launch pad access arm retracts.

T-0:50 — Endeavour transfers from ground to internal power.

T-0:31 — Endeavour's onboard computers take over countdown.

"Ten, nine, eight, seven . . ."

T-minus 0:06.6 — Endeavour revs up her three main engines.

". . . six, five, four . . ."

Five thousand people fall silent.

". . . three, two, one . . ."

The solid rocket boosters ignite. A light like the sun explodes from beneath the shuttle. It bathes the sky, the water, and 5,000 space fans, mouths agape, in a warm glow. Exhaust spews out in all directions, brilliant orange, rolling and boiling like cumulus clouds in time lapse.

Next, the sound. Somehow, I sense it rushing straight at me. Then it crashes like a breaking wave, a crackling roar. Violent compression waves snap against my chest cavity, drumming the breath out of me.

Then that light like the sun rises like the sun, pushing four and a half million pounds of machine and man above it at an improbably slow pace. I half expect the whole mass to just tumble over sideways. But somehow seven million pounds of thrust all work in the right direction.

"Endeavour has cleared the launch tower."

Once she's decided she's on her way, there's no stopping her. Within seconds, our heads are craning upward to match Endeavour's acceleration. The astronauts onboard are sucked into their seats by the pull of 3 Gs.

In just one minute, Endeavour is all but a brilliant speck, and somehow, among that pressing crowd, I'm struck by a pang of loneliness. "Wait!" I want to call out. "You forgot me!" For us Earthbound mortals, a launch is the climax of our vicarious space travel experience. For the Endeavour crew, this adventure is just beginning.

At T-plus two minutes, Endeavour is 32 miles away. With binoculars, I can barely make out the detachment of the solid boosters. Over the next six minutes, Endeavour's main engines will exhaust the external fuel tank, throttling away with the equivalent of 37 million horsepower. And then the external tank, too, will be jettisoned. The engines will cut out. Endeavour and her crew will slip silently into orbit. What a ride!

But from here, I'm left only to imagine. By moonlight, my eyes trace a white thread of exhaust that trails into the cosmos. It's a wispy, ephemeral thread, but it tugs at my curiosity with undying force. ■

Djuna Ivereigh is a freelance writer and photographer based in California. To learn more about her escapades, visit www.tpp.org.

Even if prime public viewing areas are filled to capacity, it's still worth the time and effort to witness a launch from several miles away.

KSC Visitor Center

Casting a

Learn how to explain to children what is happening in the sky when the sun and moon play hide-and-seek.

by Jeanette Brown

Remember Eeyore? Winnie the Pooh's poor, unfortunate friend? Not only was his tail attached with a push pin, but he was frightened out of his wits by his very own shadow. If only he'd understood that shadows are responsible for some of the most beautiful and grand spectacles of nature. Obviously, no one explained to him the phenomenon of eclipses.

No child should suffer Eeyore's fate — especially when eclipses and the alignment that causes the shadows can be so easy to explain and understand. And with a European eclipse viewing opportunity on tap for this month, there's no time like the present to help teach the concepts behind the show in the sky. Even if your children won't get to see this one for themselves, they'll get to understand exactly why that is and begin to look forward to more eclipses in the future.

An eclipse is defined as the passing of one body into the shadow of another — and eclipses of various sorts are taking place throughout the solar system all the time. For the purpose of this article, though, we will focus on the two types of eclipses, lunar and solar, that involve the three celestial bodies most of us know best, the moon, the sun, and Earth.

Let's look first at lunar eclipses. Very simply, a lunar eclipse takes place when Earth's shadow is cast on the moon, darkening its surface. For a lunar eclipse to occur, the moon must be on the side of Earth opposite the sun, or in other words, in full moon phase.

Shadow

But do we see a lunar eclipse each time the moon is full? No. Let's look at why. Earth circles the sun once a year along an orbit known as the ecliptic, and the sun, Earth, and the shadow made by sunlight falling on Earth all fall within this orbit. Meanwhile, the moon makes its own monthly orbit around Earth. This orbit, however, is tilted a little bit (5 degrees) from the plane of the ecliptic. During its full phase, the moon passes very close to Earth's shadow, but because of the slight tilt of its orbit, it usually passes just above or below it. However, Earth's and the moon's orbital planes will always have two points of intersection, and when the moon reaches these points, it passes directly through Earth's shadow; and, voilà, we have a lunar eclipse.

The entire night side of Earth faces the full moon, so on the occasions when the full moon does pass through Earth's shadow, half of Earth's inhabitants get to watch. What's more, it takes several hours (almost six) for the moon to move through Earth's shadow, so not only is the spectacle visible to lots of people, it lasts for a long stretch of time.

Solar eclipses, on the other hand, are not visible to as many people or for as long a time. To understand why this is the case, we need to examine the other ways in which the two types of eclipses differ. In the case of a solar eclipse, the moon is in its new phase, positioned between the sun and Earth. In reality, the moon and sun are vastly different in size — with the sun being about 400 times bigger than the moon. But in an interesting coincidence, the sun is also about 400 times farther away from Earth than the moon, meaning that to an earthly observer the sun and moon appear to be about the same size. Therefore, when the moon passes directly between us and the sun, it can block out the sun's light momentarily, creating what we know to be a solar eclipse.

Kids' Corner

As is the case with lunar eclipses, a solar eclipse can only take place when the moon crosses the plane of the ecliptic at its new phase. All other times the moon passes just above or just below the sun. But just as with lunar eclipses, about once every six months the moon is in the right spot to cut off light from the sun and reward patient observers on Earth with a spectacular sight.

But because the moon's shadow is so small, it does not cast darkness over all the Earth in the way that Earth's shadow can darken the entire moon during a lunar eclipse. Instead, the moon's shadow falls on just a narrow swath of Earth's surface, and only the people in this small portion will see a total solar eclipse. This zone of darkness where the sun will be completely blocked from view is called the umbra, or the path of totality. Those in the outer region of the shadow will see the moon block only part of the sun's surface; this area adjacent to the umbra is called the penumbra. Observers within the penumbra get to view a partial solar eclipse, which appears as if a bite has been taken out of the sun. During this month's solar eclipse, these concepts will be made very clear. The path of totality is along a line from the Atlantic Ocean south of Nova Scotia to the Bay of Bengal southeast of India, so those positioned along this line will see a total solar eclipse. The viewing range of the partial eclipse will stretch 5,500 miles (9,000 km) from north to south of the path of totality.

A solar eclipse also does not last as long as a lunar eclipse because Earth is much bigger than the moon, so its shadow is also much bigger, and the moon takes longer to traverse it. The complete phenomenon of a total solar eclipse lasts between two and three hours, and just a few minutes for the total phase, the portion of the eclipse when the moon completely obscures the sun.

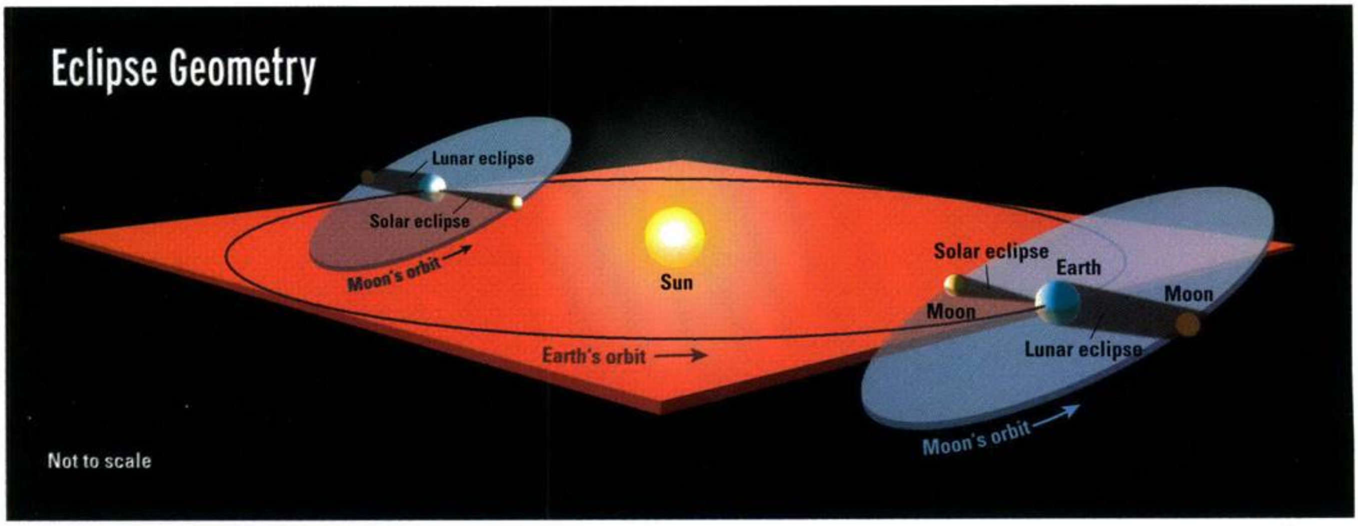
Eclipses can be modeled in a simple activity similar to one used to teach the phases of the moon (see "It's Just a Phase," April 1999). Letting children take an active role helps to make concepts more tangible and learning them more fun. All that's needed for the activity is a light source such as a clear 100-watt bulb either on a lamp stand with its shade removed or a light clamp, a darkened room for the demonstration, and one Styrofoam ball pushed onto the sharpened tip of a pencil for each child.

With their own heads representing Earth and holding their "moons on stick" at arm's length, have the children move the moon balls in orbit until the light from the "sun" is completely blocked. Explain to them that this is what happens during a solar eclipse and ask them to tell you what phase the moon must be in for it to take place. Then have them move the moon ball farther in its orbit, until the children's own shadows are cast on the moon — a lunar eclipse. Again, ask what phase the moon must be in for a lunar eclipse to occur.

As the kids begin to understand what causes each type of eclipse, ask them to pair up. Have one partner hold the moon ball so that it produces a solar eclipse and have the other partner look at the shadow of the moon falling on the face of his or her partner. Reminding them to imagine that the head of the child holding the moon ball is Earth, ask from what part of Earth people would be able to see the solar eclipse. Then have the child move the moon ball through its orbit until a lunar eclipse is produced. Now ask whether more people would be able to see a solar eclipse or a lunar eclipse. Encourage the children to explain the reasons behind their answers.

To make the concepts even clearer, you might try using an inflatable globe. Have one child hold the globe in place while the other child orbits the globe with the moon ball. Ask the kids to simulate a solar eclipse and examine which portion of the globe falls in the moon's shadow. Make sure the kids understand that in the shadowed space on the globe, people will see a total solar eclipse, while on either side of the

This total lunar eclipse on September 17, 1997, occurred on an important holiday, Chu-Sok, for those in Seoul, Korea. Park Chun-Ki



As the moon orbits Earth, an eclipse will only occur when the moon's plane intersects the ecliptic (Earth's orbital plane around the sun). The ecliptic takes its name from the fact that eclipses occur when the moon is near the plane of the ecliptic. *Astronomy*: Elisabeth Rowan

This total lunar eclipse on September 16, 1997, was captured over Plobsheim, France, a few minutes before totality. Jason P. Hatton

shadow, they will see a partial eclipse, and on the opposite side of the globe they will miss the eclipse entirely because it will occur during what, for them, is night. Encourage kids to manipulate the globe so that the region they live in comes to rest in the path of totality. Or use this month's eclipse as a model — help children understand whether they will be able to see the eclipse from where they live. Why or why not?

As these ideas begin to sink in, the kids should be ready to explain what they've learned to someone else. A perfect opportunity to have a visitor drop by, perhaps? We've all got friends who owe us favors . . . and in this situation mine would be dressed as Eeyore, with a cluster of kids around eager to explain why he shouldn't be afraid of his shadow. ▣

Jeanette Brown is a graduate student at NYU. Her most recent article was Astronomy's *Kids' Corner feature, "It's Just a Phase," April 1999.*

Fun Facts

- **During a total lunar eclipse, the moon looks red because sunlight is going through Earth's atmosphere on its way to the moon. Red light's longer wavelength can pass through the atmosphere more easily than the other colors.**
- **If you stood on the moon and looked back at Earth during a total lunar eclipse, Earth would look as if it had a red ring around it.**
- **In Viking mythology, one of the sky wolves captures the moon during a total lunar eclipse. Their stories tell of the moon being trapped and bleeding in the wolf's jaws.**
- **The ancient Chinese told stories of a giant celestial dragon devouring the sun bite by bite during a solar eclipse.**
- **Lunar eclipses are slightly more common than solar eclipses. There are 1.03 lunar eclipses for every solar eclipse.**
- **Native American Chumash rock art motifs may depict total and annular eclipses of the sun. These designs show a totally black disk in one, while the other has a black disk with a white ring, or border, around it. The sun was the chief god to the Chumash.**
- **If you travel to see the darkening of the sky this August, you may want to know how to recognize the words "total solar eclipse" in other languages. Here is a sampling:**

French	**eclipse totale de soleil**
German	**totale Sonnenfinsternis**
Hungarian	**napfogyatkozá**
Slovenian	**popolni soncni mrk**
Romanian	**eclipsa solara totala / eclipsa totala de Soare**
Turkish	**tam gunes tutulmasi**
Hindi	**poorna surya grahana**

— Andrea Gianopoulos

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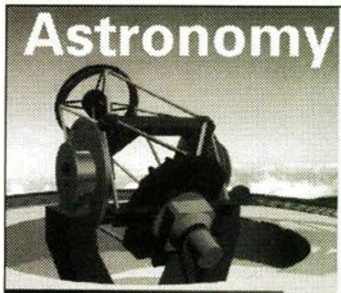

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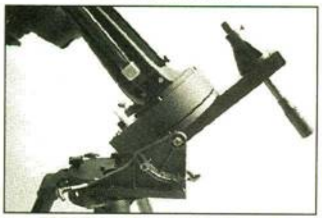

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EURO ECLIPSE

More than two minutes of totality await those heading to Europe or Asia for August's solar eclipse.

by Richard Talcott

Like two cars speeding toward the same intersection in some wild movie sequence, the sun and moon are heading inexorably toward the same spot in the sky. But there'll be no screeching brakes, no twisted metal, and no fiery collision. When the two worlds reach their date with destiny, nearly 100 million miles of space will separate them — and neither will experience anything out of the ordinary.

The same can't be said for Earth, however. When the sun and moon align on August 11, 1999, a slender cone of darkness will cut a narrow swath across Europe and Asia, turning day to night and rewarding all who stand in the path with a sight they won't soon forget. The moon's dark void will completely cover the brilliant solar disk for up to 2 minutes and 25 seconds, as flaming-red prominences jut above the moon's limb and ghostly coronal streamers outline the extent of our star's outer atmosphere.

The dark inner part of the moon's shadow, called the umbra and the region from which totality can be seen, first touches Earth at daybreak in the western North Atlantic. It then speeds across the ocean, making its first landfall in southwestern England some 40 minutes later.

Not since June 1927 has a total solar eclipse graced the skies above Great Britain, a location that should be dear to the heart of all eclipse watchers. On May 15, 1836, the moon passed in front of the sun as seen from southern Scotland. Although it was only an annular eclipse, English astronomer Francis Baily was there to view it. He watched as the moon nearly covered the sun and light from the sun's edge was blocked by tall mountains along the lunar limb but poured through deep valleys. Baily's description of the sun's bead-like appearance motivated the name Baily's beads. But more importantly, Baily's description of the event so inspired others that he helped start the practice of eclipse chasing.

Crossing the Continent

After plunging the coast of Cornwall into darkness, the umbral shadow heads across the English Channel and begins its journey through continental Europe. France, Germany, Austria, Hungary, Romania, and Bulgaria all take direct hits, while southern Belgium and Luxembourg and northern Slovenia and Yugoslavia lie on the umbral shadow's edge. The umbra next traverses the Black Sea prior to crossing Turkey, Iraq, Iran, Pakistan, and India before leaving Earth at sunset in the Bay of Bengal.

Access to the path of totality will be far easier than for most eclipses, which seem to have a proclivity for exotic, out-of-the-way places. Major cities in the path of totality include Munich and Bucharest, while Paris, Vienna, and Budapest witness 99 percent partial eclipses and make good bases for an excursion into the shadow. The extensive highway system in Europe makes it easy to get around and avoid scattered clouds on eclipse day.

The chances of the weather cooperating increase as you head eastward across Europe. Based on many years of weather statistics, the chances of seeing the eclipse from England or France are close to 50 percent. (Keep in mind that these numbers are for a stationary observer; if you keep mobile the odds improve dramatically.) Those chances improve to about 65 percent in Romania, Bulgaria, and the Black Sea and rise to more than 90 percent in the deserts of Iran and Iraq. Thereafter the odds drop precipitously, down to just 10 percent as the shadow leaves the east coast of India.

Solar prominences are just one of the spectacular sights eclipse chasers may see this month. Jeff C. Shepherd

The bright gossamer streamers of the sun's outer atmosphere, the corona, appear at totality. David M. Beraru

But remember the old adage of the meteorologist: Climate is what you expect, but weather is what you get. Statistically, promising weather may be indicated for a particular place at a particular time of year, but no one actually knows what the weather will be like on any given day at one specific place. Ask those who traveled to Hawaii for the July 1991 eclipse, where the prospects were excellent but clouds nevertheless obscured the view.

On a Clear Day

With nearly three hours between first contact — when the moon first encroaches on the sun's disk — and the end of the eclipse, you might think there's plenty of time sit back, relax, and enjoy the eclipse at a leisurely pace. Nothing could be further from the truth. What may seem like lots of time beforehand turns into a fleeting moment during the eclipse. And to compound the problem, most of the action occurs during the few minutes right around totality.

If you intend to photograph the eclipse or view it with a telescope, plan on arriving at your observing site at least an hour or two before first contact. This should give you plenty of time to set up equipment and be sure it's operating properly. After all, you don't want to find out your camera's not working just as totality begins.

Although the moon moves steadily across the face of the sun, the signs of impending totality are few and subtle. You'll probably feel compelled to glance at the sun occasionally, just to confirm that the moon is keeping to

schedule. (Never look at the sun directly during the partial phases without protection; see "Safety First" on page 88 for safe ways to view the eclipse.)

About 45 minutes after first contact and some 30 minutes before totality, a perceptive eye should start to notice changes. Look at how sharp your shadow appears. As the source of light in the sky grows ever smaller, individual hairs on your head, arms, and legs will stand out in bold relief. The shadows under trees offer an even more exhilarating sight. As sunlight filters through the gaps between leaves, each serves as a pinhole and projects an image of the eclipsed sun. You could easily see thousands of tiny crescent suns dancing on the ground.

The sky doesn't grow noticeably darker until the sun wanes to a thin crescent, approximately ten minutes before totality. That's a good time to search for Venus, the brightest object (besides the sun, of course) in the sky. Glowing at magnitude –4.1, the brilliant planet lies some 15° east of the sun. Once totality arrives, Venus will be joined by Mercury, Sirius, Procyon, and the stars of Orion in the west and the stars of the Big Dipper nearly overhead.

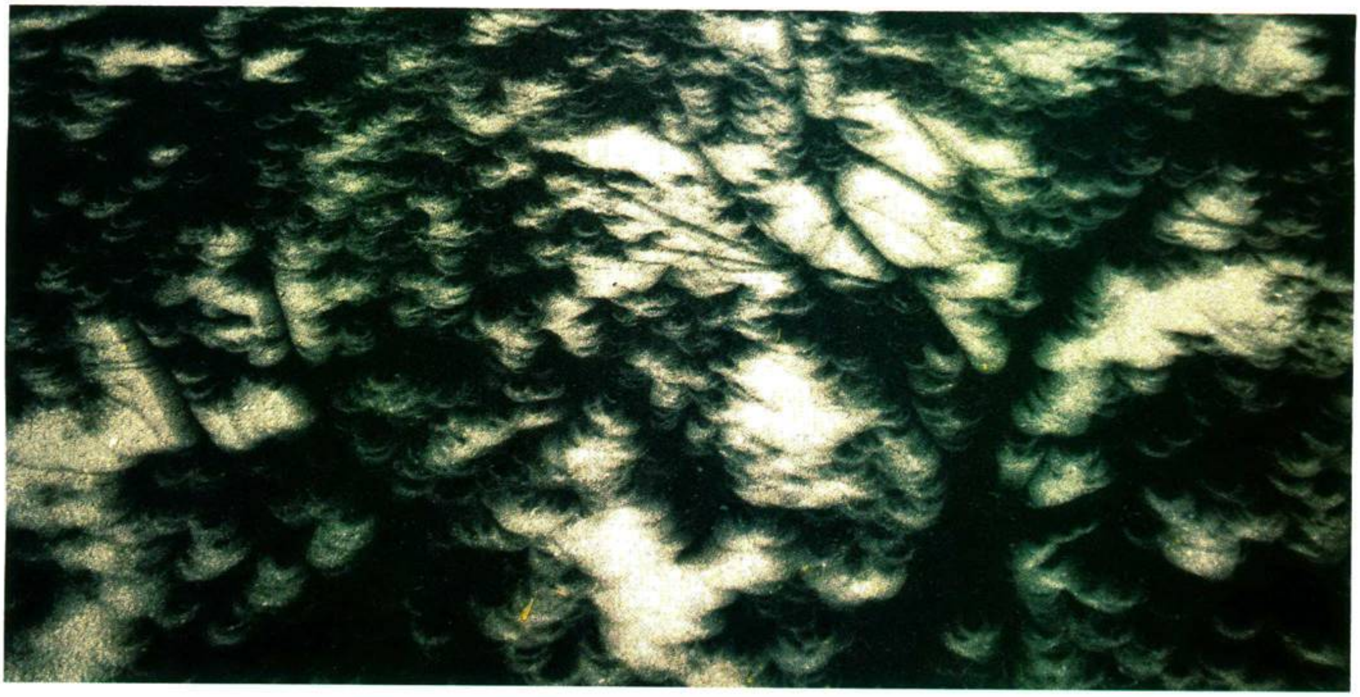
In the final minute before totality, the thinning crescent starts to break up into what are called Baily's beads, as mountains along the edge of the moon poke through. With 15 seconds to go, briefly tear yourself away from the sun and look toward the western horizon. There you will see the moon's shadow rushing toward you at some 1,500 miles per hour, a supersonic messenger proclaiming the impending arrival of totality. One glittering marvel awaits: As sunlight pours through the final and deepest valley along the moon's advancing limb, the sun looks for all the world like a gigantic jewel, earning it the name "diamond ring."

Once the diamond ring disappears, it's safe to take off any solar filters and enjoy the glory of totality. First and foremost, examine the sun's gossamer corona, the pearly-white outer atmosphere of our star that typically displays a wealth of delicate detail. The hottest part of the solar atmosphere, the corona stretches millions of miles above the surface and glows at temperatures of a million degrees. No one can predict exactly what the corona will look like on August 11, but with solar activity expected to be high — the peak of the 11-year sunspot cycle should come in 2000 — the odds favor a round and fairly symmetric corona.

Although it might be tempting, don't spend all of totality observing the corona. There are lots of other things going on that are well worth a look. The other major solar feature to watch for are prominences, the reddish tongues of gas that arc into the corona. Your best view of these will come though binoculars or a telescope. And don't forget at least a quick look to take in your surroundings. Scan the sky to see how many planets and stars you can spot. Then observe the delicate twilight colors that ring the entire horizon. With only two minutes and change of totality, you'll have to be quick to catch it all.

A second diamond ring announces the end of the total phase and the time to replace all the solar filters on your equipment. Next you'll see Baily's beads and all the other phenomena of the partial phases played in reverse order. Although many people lose interest by this stage, it's worth sticking around a while longer. With the anticipation of

Left: Totality as viewed from the small village of Kolaghat in India on October 14, 1995. John Post



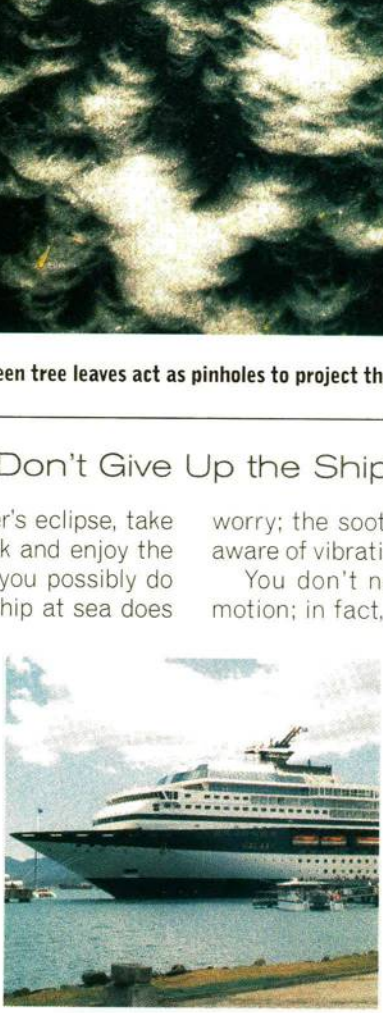
Don't spend all your time looking up. Tiny gaps between tree leaves act as pinholes to project thousands of crescent suns on the ground. David Fasules

Don't Give Up the Ship

If you are taking a cruise to this summer's eclipse, take your telescope or binoculars out on deck and enjoy the dark, unobstructed night sky. How can you possibly do that on a rolling, pitching platform? A ship at sea does not move as much as you might expect. Sailing to the '98 eclipse aboard a relatively small ship (18,000 tons), I discovered that the sun generally remained within a 2.5° field of view even when the ship was moving at full speed. In addition to modest pitching and rolling, ships also vibrate. Parts of your ship, though, will vibrate less than others.

Any pair of handheld binoculars should serve you well, as will a wide-field telescope. Just make sure your field of view is at least 2°. Use an alt-azimuth mount if you can, and keep lock nuts loose so you can easily follow your target if it floats out of the field. If you have an equatorial mount, point your polar axis at the zenith and use it as an alt-azimuth mount.

Before you set up, scout the decks for dark locations. If there is an open deck below the bridge, it will likely be kept dark to prevent glare on the windows of the bridge above. It makes a good observing site, but it can be windy. If the ship is making 18 knots into a 20-knot head wind, don't set up toward the bow unless you are prepared to brave a wind of more than 40 miles an hour. Keep in mind, too, which way the plume from the ship's smokestack is blowing. It will interfere with seeing and can deposit fine soot on you and your equipment. Don't worry; the soot brushes or blows off easily. Finally, be aware of vibration in selecting your site.



You can observe at sea. Evelyn Talcott

You don't need to set up amidships to minimize motion; in fact, it won't help. If you are observing from the stern as the ship pitches forward, you will rise a greater distance than another observer standing closer to the middle of the ship. But you will both move through the same angle. Since there is no parallax, the equal angular shift of both observers will mean an equal image shift in their telescopes.

The ship's vibration will make it difficult to concentrate on fine detail, so skip the moon and planets and look for clusters and nebulae. When you are observing, concentrate on the view at the end of each roll, as the ship stops moving in one direction and starts to move back the other way. At the same time, use the ship's motion to help you find and observe faint targets. Because the human eye is extremely sensitive to motion, a faint target is easier to see when it is moving. The ship does the work for you. Simply follow your target in the eyepiece and you will use your light-sensitive peripheral vision more than you do on solid ground.

So turn your eyes to the night sky on that cruise. Take the right equipment, set up in the right place, work with the sea and hunt the right targets. You will be surprised at how much you will see from your moving observatory. — *Jeffrey S. Rothstein*

totality no longer hanging over you, you may even find yourself better able to appreciate the partial phases. (This is a great time to take photos of crescents under a tree, for example.)

Capturing the Eclipse on Film

Although nothing quite matches seeing a solar eclipse with your own eyes, most people also want to take home photographic evidence of the event. Fortunately, capturing stunning images of the eclipsed sun is not that hard — all it takes is the right combination of film and lens.

You can land a stunning eclipse photo with nothing more than a 50mm lens attached to a camera and mounted on a sturdy tripod. Granted, the eclipsed sun will appear a scant 0.5 mm across on the film, so you won't capture any prominence detail or fill the frame with the glorious corona. Composition is what sets off these scenic shots. An ocean vista, a city skyline, or even a relatively mundane foreground comes alive when punctuated by an eclipsed sun. Such pictures probably capture the feeling of being at the eclipse better than any other type of photo.

The key to getting a great photo is to plan the shot well ahead of time. Know where the sun will be and scout out the perfect foreground to create the greatest pictorial impact. Framing the shot will be a little tricky with this eclipse because the sun rides fairly high in the sky: some 45° above the horizon in England and between 50° and 60° in the rest of Europe and Turkey. A standard 50mm lens on a 35mm camera captures a field about 40° wide by 27° tall (or 27° by 40° if turned vertically), so you won't get both the sun and a level horizon at the same time. If that's important to you, try

Safety First

Looking at the sun is dangerous, and never more so than during the partial phases of an eclipse. With the sun's total brightness diminished, it's easier to look at the sun for an extended period, and the eclipse makes us want to stare at the sun. Unfortunately, huge amounts of visible, ultraviolet, and infrared radiation can quickly damage the retina of an unprotected eye.

Three types of filter material will do the job. An inexpensive but perfectly safe filter is a #14 arc-welder's glass, available at welding supply stores. Mylar filters and metal-on-glass filters also work well and can be manufactured to fit over the front end of a telescope. Manufacturers and dealers advertise these filters in *Astronomy*. You can also view the partial phases indirectly by projecting an image of the sun by simply interlacing your fingers or punching a pinhole in a piece of cardboard. Keep your back to the sun and look at the image formed on the ground as sunlight passes through the opening.

Never use one of the so-called "sun filters" that screws into a telescope's eyepiece and is included with some department-store telescopes. Also avoid using black-and-white or color film, sunglasses, smoked glass, polarizing filters, x-ray film, or any aluminized Mylar sold as "space blankets," window insulation, or candy wrappers. All of these limit the amount of visible light transmitted but do little or nothing to block the hazardous infrared. — *R.T.*

a 35mm lens with its 54° by 38° field or a 28mm lens that will yield a 73° by 50° field.

Another option to consider is a fisheye lens, which will capture the entire sky along with the horizon. Simply aim the camera straight up and you'll record the eclipsed sun along with the surreal twilight glow ringing the horizon.

Whichever method you try, use moderate-speed film and bracket your exposures from about ¼ second up to 10 seconds. The shorter exposures should more accurately reflect your visual impression of the eclipse, while the longer exposures will reveal subtle colors, fainter stars, and landscape details that you may not have seen.

If fiery-red prominences or coronal streamers are more your cup of tea, then you'll need a lens with a much longer focal length. The size of the image on the film increases proportionally to the focal length of the lens, so a 500mm telephoto gives a solar image ten times as large as a 50mm lens does, or about 4.5 mm across. For detailed shots, however, use optics in the 750mm to 2,000mm range (corresponding to an image size of from 7 mm to 18 mm). A telephoto lens with a 2x or 3x teleconverter will work, though they rarely have the optical quality of a good lens. Better yet is to use a telescope as your camera's lens. You don't need a massive scope — a 3- or 4-inch telescope works great and also transports much more easily.

These long focal lengths magnify the sun tremendously, and the slightest motion of the camera or lens can noticeably blur the image. A sturdy tripod may be the best investment you can make in eclipse photography, but also seek out and eliminate other sources of vibration. To avoid accidental bumps during exposures, try to set up well away from the crowd. Use a cable release to trip the shutter. And finally, exploit your camera's mirror lock-up feature, if it has one.

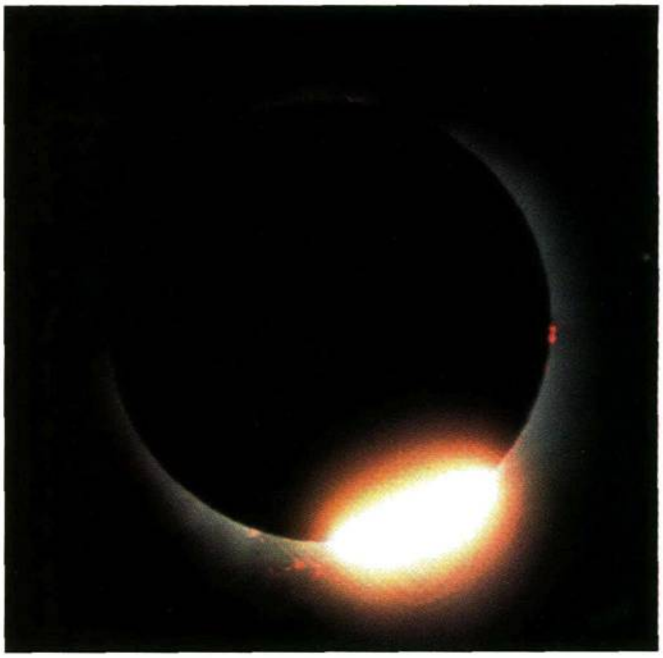
Films and Exposures

Many people think that the darkened sky of an eclipse requires fast film and long exposures. Fortunately, that's not true — most of the solar features you'll want to record are surprisingly bright. Experienced eclipse photographers choose film with an ISO rating of 100 or so, which will capture sharp detail and retain that detail when enlarged. Faster films show more noticeable grain but work well if you're viewing from the deck of a cruise ship. A 400 speed film will help minimize the image blur caused by the constant rolling motion of the ship.

Photographing the partial phases of the eclipse requires a filter to protect the camera from the sun's heat. The best filters are aluminized Mylar or metal-on-glass types that fit over the front end of the telescope or telephoto lens. There is a little more leeway with photographic filters than with filters for viewing the sun directly because the eye is sensitive to ultraviolet and infrared radiation while film is not. A 5.0 neutral density photographic filter will work fine (though never view the sun directly with it), but shade the camera between exposures to avoid overheating it or the film.

With ISO 100 film, your exposures should run about 1/125 second at f/8 during the partial phases. But remember to bracket your exposures by at least two or three stops because the optimal exposure depends on what filter you use and the sky conditions that day.

Left page: This series of exposures was produced by taking an image every eight minutes. Bill Sterne



A "diamond ring" can be seen just before totality begins and just after it ends. Eric Matteson

During totality, the filters come off and you shoot the sun directly. Contrary to popular belief, exposure times aren't all that important. The reason: An exposure of almost any length will yield a good shot. A short exposure captures the reddish prominences, an intermediate exposure reveals the inner corona, and a long exposure brings out the outer corona.

Follow a simple plan for your total eclipse shots. Ten to fifteen minutes before totality, load the camera with a fresh roll of 36-exposure film even if you have unshot frames left on the current roll. After totality begins and the filter is off, manually focus the camera as accurately as you can. A bright prominence or the moon's dark limb make good focusing targets. The time you spend focusing will more than be paid back in crisp images.

With a telephoto lens, set the f-stop to between 4 and 5.6. To capture the fleeting Baily's beads or the diamond ring, shoot at speeds of 1/1000 to 1/125 of a second. Once the diamond ring disappears, keep exposures short (1/500 to 1/60 of a second) to get good photos of prominences. Then gradually lengthen the exposures up to a maximum of 1 or 2 seconds to grab the corona. Follow a similar routine with a telescope, though exposure times will vary depending on the scope's focal ratio. (This number should be marked somewhere on the telescope's tube.) With a fast scope (f/4 to f/8), try the same times recommended for the telephoto lens. For an f/10 scope, increase the exposures by about one stop, and for an f/16 scope, go up an additional stop.

As much as you may want beautiful photos, however, don't neglect actually looking at the eclipsed sun. More than one observer has spent totality looking through a camera's viewfinder and missed the ambiance of totality. Your memories of viewing the eclipse will likely outweigh any photos you could possibly take, so don't blow it by getting too camera happy. After all, there won't be another total solar eclipse to chase until June 2001.

Richard Talcott is an associate editor for Astronomy *magazine.*

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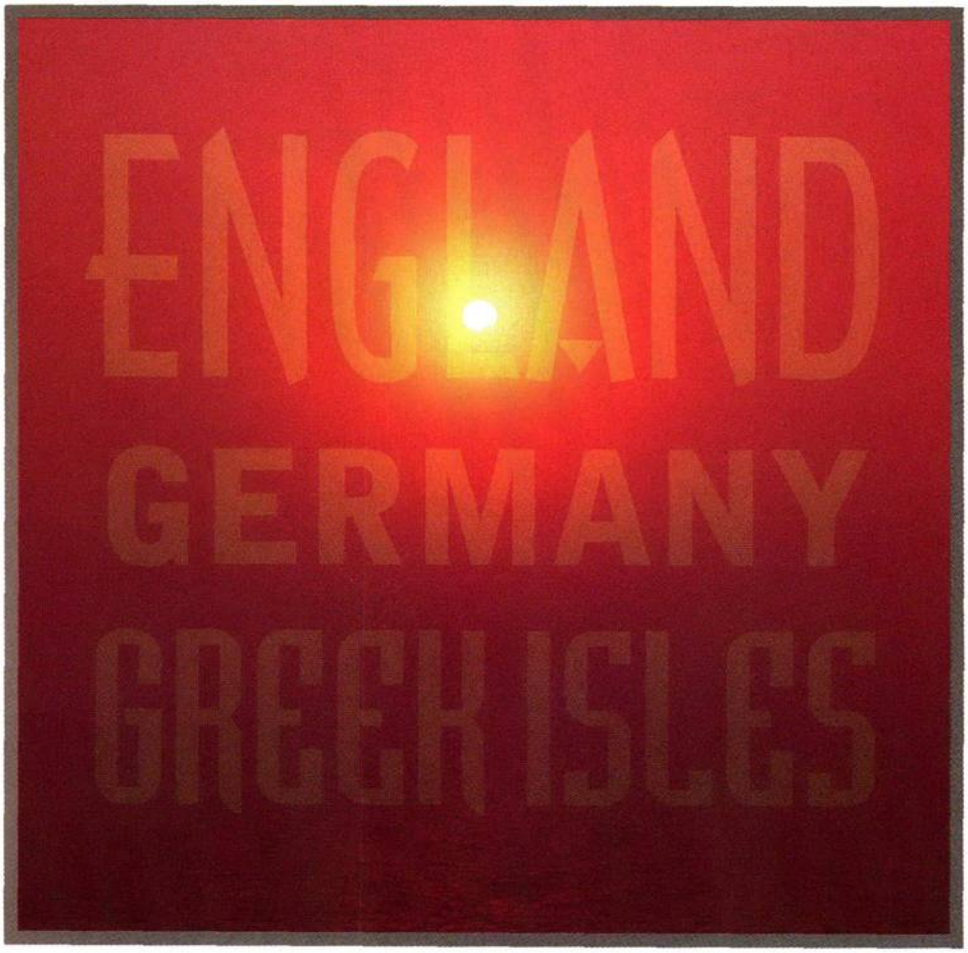

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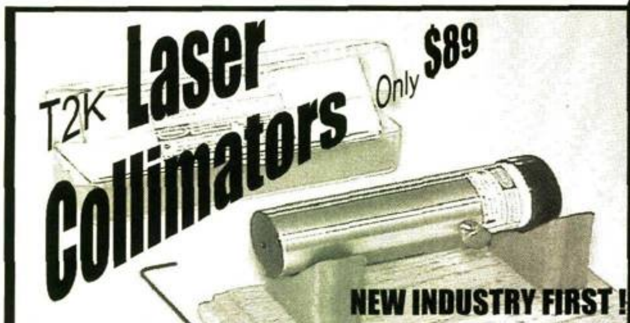

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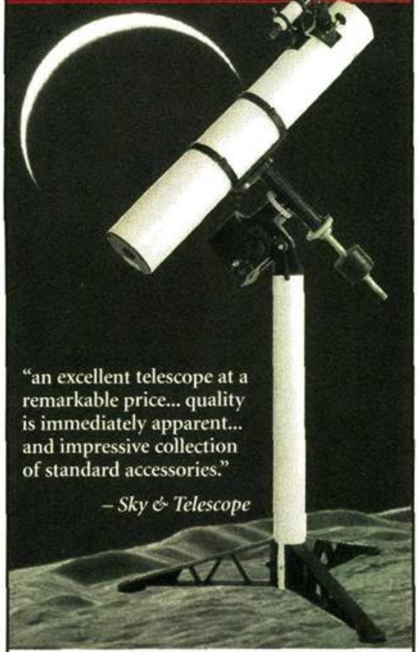

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Astronomy: Terri Field

Q: Considering relativity, would it be possible to look far enough into space and see objects behind you? *— Justen Van Landingham, Spanish Fort, Alabama*

A: Scientists theorize that there are three possible shapes for the universe: flat, open, and closed, each affecting how particles of light, known as photons, travel.

A flat universe will expand forever, slowing down only as a result of its own gravity. Mathematical calculations predict that a flat universe will eventually cease expanding after an infinite amount of time. On the other hand, an open universe will expand forever. And in a closed universe, gravity from stars, planets, galaxies, black holes, and other objects will eventually stop the expansion and cause an enormous collapse.

Theoretically, a photon could circumnavigate a closed and expanding universe. You can compare the photon's journey to an ant crawling around the surface of a slowly inflating balloon. From her perspective, she is traveling in a straight line, but eventually she would end up back where she started.

On a universal scale, though, it would be tough. An expanding universe requires a photon to use energy to move through the universe rather than simply coast, much like a person on a bicycle has to use energy to pedal up a hill. As a result, the photon's radiation frequency decreases and its wavelength shifts, something we call the cosmological redshift. A photon trying to traverse the universe would eventually lose so much energy that it would become unobservable for all intents and purposes.

The latest findings show that the universe is open anyway, so a photon will just travel forever, never circling back. That's a long way to pedal! — *Phil Plait, The Bad Astronomy Web Page: http://www.badastronomy.com*

Q: Current hypothesis states that a body collided with early Earth, throwing off a large amount of matter that later became the moon. Have any scientists speculated as to what Earth might be like had not such an impact occurred? *— A. R. Timmerman, Ridgefield, Connecticut*

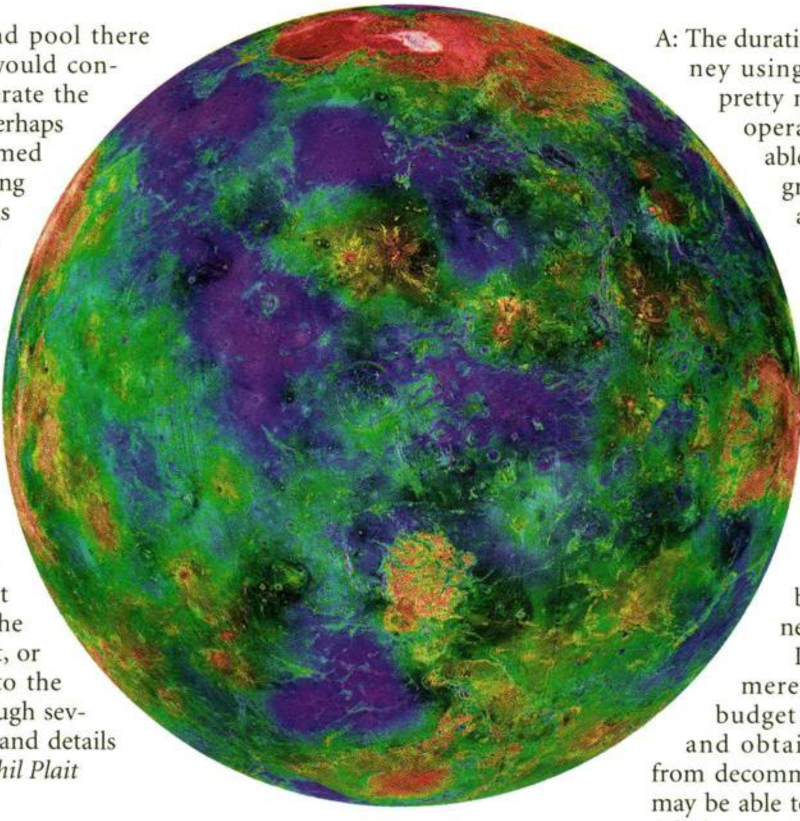
A: Earth would be profoundly different if the moon didn't exist. For one, the hypothesized collision that formed the moon is also probably the event that knocked Earth into its present 23.5 degree tilt. This tilt is responsible for the seasons, so without it, we would only have very slight seasons due to the elliptical shape of Earth's orbit. Summer would be marked with a temperatures a few degrees warmer than winter, when Earth is a bit farther from the sun.

The moon's gravity tugs on Earth, as well. Without this force, we wouldn't have tides, and our planet would spin faster, too. Right after the moon formed, it was very close to Earth, and the tides were much stronger. Over time, the moon got farther away — a distance that continues to increase — and Earth's rotation gradually slowed. We can extrapolate that Earth rotated much faster then, and so without the moon, Earth might today rotate much faster, giving us shorter days.

Most profoundly, many scientists theorize that life itself might owe its existence to the moon. As primitive amino acids and proteins built up in seawater, they would be quickly broken down in the open water. However, water can collect on flat rocks near

Life on Earth may owe its very existence to the moon. John Bucce beaches at high tide and pool there during low tide. This would concentrate and also accelerate the chemistry in the water. Perhaps complex molecules formed in these tidal pools, leading to multi-celled organisms and eventually us. If true, then without the moon, life might never have arisen on Earth.

What If the Moon Didn't Exist by Neil F. Comins provides a lot more detail about this topic. The book discusses not only what things might have been like had the moon never formed, but also what Earth would be like if the moon orbited closer to it, or if Earth orbited closer to the sun. The book goes through several "what if?" scenarios and details the changes in each. — *Phil Plait*



On Venus, the sun rises in the west and one day is equal to about 117 Earth days. JPL

Q: I read that a Venus day is 243 Earth days, and a Venus year is 225 Earth days. How could a day be longer than a year? — *Jonathan Weinraub, Wyckoff, New Jersey*

A: This is an excellent question that exposes a common misconception. The length of a day on Venus is not 243 Earth days. This is the planet's period of rotation. A planet's period of rotation is measured with respect to the stars (sidereal rotation period) while the length of a day is measured with respect to the sun (synodic rotation period). Because Venus rotates so slowly, in the time it takes for a single venusian day to pass, the planet moves a significant distance in its orbit around the sun. The combined motion causes the length of a venusian day, the time from one sunrise to the next, to be about 117 Earth days. So, although Venus's period of rotation is longer than the length of its year, the length of its day is not.

If you were standing on Venus (something I don't recommend) looking to the east through the thick cloud cover to see sunrise, you'd miss it. On Venus, the sun rises in the west. This is because Venus's axis of rotation is titled 177° to its orbital plane, compared to the 23.5° tilt of Earth's axis. Venus appears to be flipped over on its axis, rotating in the opposite direction compared to all the other planets of the solar system except Uranus.

As to why Venus has such a slow and retrograde rotation, we really don't know. Some planetary scientists suggest that a combination of tidal forces exerted by the sun and strong east-west winds in the dense atmosphere over time slowed and eventually reversed the direction of the planet's rotation. Others believe the rotation of Venus has always been retrograde, the spin direction established by the accretion of planetesimals. — *Thomas Watters, National Air and Space Museum, Smithsonian Institution*

Q: Given present technology, and ignoring the political difficulties in using certain types of fuels, how long would a manned trip to the nearest star — other than the sun — take? How long would it take for an unmanned probe? — *Clifford Sears, Pittsford, New York*

A: The duration of an interstellar journey using current technology is pretty much a function of your operating budget. If you are able to use the entire world gross national product for a few decades or a century, you might be able to manufacture (and safely store) enough antimatter to launch a robot (or even a small peopled expedition) to one of the nearest stars, say Alpha Centauri, on a trip of a few decades in duration. Decelerating the ship, if required, could be accomplished by magnetic braking.

If instead you can tap merely the world's military budget for a number of years and obtain fusionable isotopes from decommissioned H-bombs, you may be able to store this stuff in orbit (if, that is, the world's citizens trust you). A fusion-pulse ship propelled by this stuff requires a few centuries to reach the nearest star.

If you are financially strapped but have a great deal of time, you have the option of launching a solar-sail propelled probe with the sail unfurled as close to the sun as possible. However, peopled solar-sail starships require 1,000 years or more for the crossing to Alpha Centauri. It can be done faster with a thin-film robot, which could probably be designed to make the flight in 500 years or so. Flight time could be cut by using a sun-orbiting laser power station, but then we're talking high-cost again. These stations would require a few hundred billion dollars to develop. — *Greg Matloff, New York University and New School, co-author The Starflight Handbook (John Wiley and Sons, New York, 1989)*

CONTACT INFO

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P.O. Box 1612, Waukesha, WI 53187. Please tell us your full name and where you live. *Astronomy* regrets that due to the large volume of mail, we are unable to publish answers to all questions or respond to each one individually.

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If you want the right telescope, you need more than a camera store clerk with a price list, a surly attitude, and a wild guess.

What you *really* need are people who will take the time to listen to what *you* need, people with years of experience using and selling telescopes, people who can help you get the most telescope for your dollar. That's exactly the kind of people you'll find at ***astronomics***.

Unlike camera stores and shopping mall gift shops, telescopes are our specialty at ***astronomics***, not just a sideline. We're a family-owned full-line telescope dealer – not just a few toy telescopes stuck off in the corner of some no-help department store, toy store, or gift shop as an afterthought. We don't work on commission, so we won't try to sell you more than you need just to pad our paychecks.

We've been helping people choose the right telescope since 1979. We have the experience to help *you* pick the scope that fits your needs . . . *and your budget* . . . from the many Meade, Celestron, TeleVue, Takahashi, and Questar telescopes we stock at discount prices from $119 to $27,995. (We had 534 scopes *in stock* as we wrote this.)

astronomics. No hard sell. No guesswork. Just honest advice, the *right* telescope . . . and a good price. Call us at (405) 364-0858 and find out for yourself.

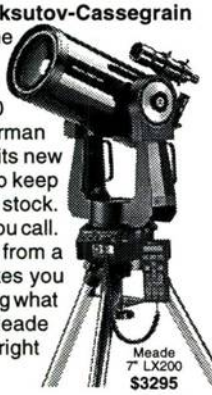
We order Meade telescopes and accessories by the ton . . . literally!

Meade
203SC
$895

The day before this copy was written, we received 305 cartons from Meade – *3¼ tons* of scopes and accessories in one shipment. We don't know of many other dealers – if any – who actually stock Meade products in those quantities . . . no matter what they claim. But we do. Meade scopes, binoculars, eyepieces, filters, Magellan computers, Barlows, off-axis guiders, illuminated reticle eyepieces, counterweights, T-adapters, tele-extenders – we have them all in stock.

It doesn't matter whether the right scope for you is a fully-computerized 8" or 10" **LX200 Schmidt-Cassegrain**; the **LX200 Maksutov-Cassegrain** 7" to the right; any of the 8" or 10" **LX50** SCTs; the 3.5" **ETX-90EC** and 5" **ETX-125EC** Maksutovs with optional go-to computer shown at the top of this page (we had 90mm in stock and over 400 125mm on order as this was written); or the German mount **203SC/500** 8" SCT, shown above left at its new lower price. If Meade is shipping it for a dealer to keep in stock, the chances are good that we *have* it in stock.

Meade prices are about the same anywhere you call. So why order a Meade telescope or accessory from a dealer who charges your credit card, then makes you wait and wait until he finally gets around to ordering what you want? Not when you can usually get the Meade you want . . . right now . . . at the right price . . . right here at ***astronomics.***



We order Celestron by the ton, too!

The day this was written, we received 4816 pounds of Celestron scopes and accessories in one shipment, giving us 287 Celestron scopes in stock for immediate shipment. We don't know of many other dealers – if any – who stock Celestron in those quantities. But we do.

Because we buy in large quantities, we can take advantage of special buys – like the Ultima 9¼ and Ultima 11 specials above right.

A Celestron Ultima 9¼ for $1999! Or an Ultima 11 for $2499!

Includes free dec motor, too!

Celestron
11" Ultima 11
$2499

To help celebrate our 20th anniversary, we made a very large purchase of Celestron 9¼" and 11" Ultima Schmidt-Cassegrains at a special price that lets us sell them for almost $400 *below* regular dealer cost!

The Ultimas come with a full length adjustable height tripod; heavy duty wedge with deluxe latitude adjuster upgrade; setting circles; manual slow motion controls; dust covers; 1.25" star diagonal; eyepiece (a 25mm SMA on the Ultima 9¼ and a 26mm Plössl on the Ultima 11); and finderscope (a 6 x 30mm on the Ultima 9¼ and a 9 x 50mm on the Ultima 11).

The built-in Ultima worm-gear DC drive operates for up to 50 hours on a single 9-volt battery and includes a built-in dual-axis drive corrector with periodic error correction, four drive speeds, a hand control, and a *free* $170 list price declination motor (normally an option that costs $119.50.)

The **Ultima 9¼** and normally optional dec motor have a combined list price of $4768 and a dealer cost of $2384. But our anniversary sale price is only $1999! Only 27 available at this special price.

The **Ultima 11** and normally optional dec motor have a combined list price of $5768 and a dealer cost of $2884. But our anniversary sale price is only $2499! Only 51 available at this special price.

We believe thse Ultima prices are the lowest you'll find *anywhere*.

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"Truly a quantum leap in binocular observing." That's how *Sky & Telescope* reviewed the image-stabilized **Canon 15 x 45mm binoculars**. They also said "astounding . . . supercrisp . . . particularly impressive was how well these binoculars compared to much larger apertures . . . totally blew away what I had seen in the 7 x 50s!" For hand-held, rock-solid, wide field observing, you can't beat the the Canon image-stabilized binoculars we keep in stock.

Our free catalog helps you pick the right Meade, Celestron, Questar, Takahashi, or TeleVue scope.

For detailed information on individual products, visit our Web site. Or you can call us at (405) 364-0858, or e-mail us, for your *free* copy of our catalog 99AST. It covers all of the telescopes and accessories we stock – from Apogee, Canon, Celestron, DayStar, JMI, Lumicon, Meade, Optec, Pentax, Questar, Rigel Systems, SBIG, Software Bisque, Takahashi, TeleVue, and more. We'll include our 8-page guide on how to pick the right scope and your discount prices on the 1000+ products we carry. (Sorry, U. S. sales only.) The catalog is yours for only the cost of a one minute telephone call. The information we send will make it the most useful minute you'll ever invest in astronomy.

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Toll-Free Order Line: **(800) 422-7876** Catalogs/Questions/Advice: **(405) 364-0858**

We'll sell you the *right* telescope.

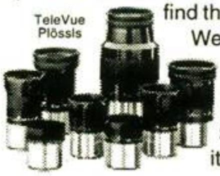
The right scope might be a TeleVue.

TeleVue TV-85 **$1995**

Hardly a week goes by that TeleVue doesn't send us a copy of a new warranty card from one of our customers – to let us read the glowing comments about the TeleVue scope they bought from us. While we're pleased to hear we've satisfied another customer, we've come to expect only praise for TeleVue scopes.

TeleVue's short focal length ultra-premium refractors give you an observing flexibility many other scopes lack. Each scope has the ability to go from very low power wide angle views (as low as 9x in some cases, with a wide 5.7° field) to very high power observing (one test report said they used 89x per inch of aperture on the Ranger, the least expensive TeleVue), all without losing optical quality.

Pronto, **Ranger**, the **TV-85** and **TV-101**, the brass **Renaissance** – all TeleVue refractors are built to the same uncompromisingly high optical and mechanical standards. And the chances are good you'll find them in stock at ***astronomics***.


TeleVue Plössls

We also stock TeleVue eyepieces, Barlows, and accessories in depth. Whether it's a Plössl, Nagler, Nagler 4, Radian, Panoptic, Paracorr, Powermate, Tele-Pod, Gibraltar, Qwik-Point, Starbeam, or BinoVue – we carry them all. If it's a TeleVue, chances are good we have it.

The right scope might be a Questar.

Questar 3.5" Standard **$3299**

For many people, the thought of a 3.5" scope that *starts* at $3399 is enough to curl their toes. But for those who want the best small telescope made, $3399 is a bargain.

Solar filters for eyepiece and finder, built-in Barlow, two ultra-premium eyepieces, a velvet-lined hard case, a star chart on the slide-on lens shade with a Moon map beneath – all are standard on a Questar . . . and unavailable from the competition.

Want a Questar, the premier portable telescope? We stock them.

The right CCD camera? It might be from Celestron, Meade, or SBIG.

SBIG ST-8 **$6450**

Meade 208XT **$495**

We stock CCD cameras in depth (we had more than 130 in inventory as this was written). We don't know of any other dealer who stocks CCD cameras in the quantities we do.

From the **Meade 201XT** autoguider at $395 and the **SBIG ST-4** autoguider/imager at $595, to the **Celestron Pixcel 237** at its new lower price of $1199, to the new enhanced blue sensitivity **SBIG ST-8** at $7350, we have the CCD cameras and guiders you want, at prices you can afford.

Plus, we stock CCD accessories – color filter wheels, AC and DC adapters, adaptive optics systems, f/3.3 telecompressors, and more.

Special demo pricing on the SBIG ST-6B and ST-8.

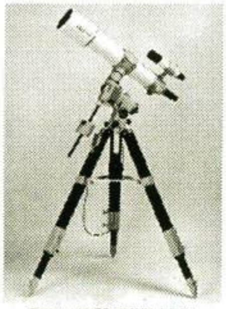
If you want a great deal on a premium quality CCD camera, we have some indistinguishable-from-new SBIG camera demos at prices that will save you up to $750! Each has a full factory warranty.

The latest low dark current version of the industry standard **ST-6B** is regularly $3025. Our special demo price is ***only $2495!***

The **ST-8**, either with or without anti-blooming, is regularly $6450. Our special demo price is ***only $5700!***

Naturally, our demo quantities are *very* limited at these low prices.

Or it might be a Takahashi.


Takahashi FS-102UH (4" f/8 fluorite/SD on EM-10USD mount)

While many people swear *at* the long delivery times quoted by some manufacturers of premium refractors, most knowledgeable astronomers swear *by* the uncompromised optical quality and fast delivery of the Takahashi refractors we keep in stock.

From the 3.1" **FS-78** to the 5" **FS-128**, we stock Takahashi fluorite/special dispersion glass apochromatic doublet refractors, mounts, and accessories – so we can deliver scopes *fast.* Why wait for up to a year to observe through an apo refractor from another manufacturer? You can be usually be viewing through a truly fine Takahashi apo only a few short days after you order from us. We stock complete Takahashi scopes on USD mounts with dual-axis 50x sidereal slewing, as well as apochromatic optical tubes only to install on your own mount.

Also available from stock is the unique Takahashi **CN-212H** 8.3" reflector that converts from an f/12.4 classical Cassegrain reflector to a very fast f/3.9 Newtonian for visual observing and astrophotography.

If you want something bigger, 6" doublet and triplet apo optical tubes and complete scopes are available on a special order basis.

If you want an apo, and want it now, it's Takahashi from ***astronomics***.

It might be this $999 Celestron C5+.

Celestron 5" C5+, shown with optional hand control, but without standard tripod **$999**

We made a special purchase on 200 **Celestron C5+** scopes that include the normally optional $298 list price tripod. Our regular price on the C5+ and tripod is $1299. But your sale price is only $999 – $300 below our regular price, and less than the normal dealer cost of the scope alone!

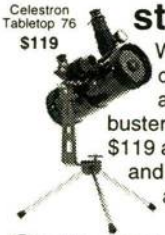
The C5+ has a tabletop mount, full length adjustable height tripod, 25mm eyepiece (50x), 6 x 30mm finder, setting circles, manual slow motion controls, dust covers, and 1.25" star diagonal. The optical tube detaches in seconds for use as a spotting scope or telephoto lens.

The built-in DC drive runs up to 50 hours on a single 9-volt battery and easily converts to a dual axis drive corrector for astrophotography by adding an optional declination motor and hand control.

In *Sky & Telescope,* the C5+ was called "a superb telescope . . . a powerful astrophotography platform." *Astronomy* praised its "superb optics" and called the C5+ "an ideal telescope for many of today's buyers . . . an excellent value in an all purpose telescope."

> I have only one regret about my recent purchase of a Meade LX50 10" SCT and accessories from Astronomics. I regret that I do not live near Norman, OK to thank you all in person for your outstanding service, knowledge, and courtesy. The field of Astronomy is fortunate to have you! **Customer Quote of the Month #88**

Dozens of economy scopes for the star-gazer on a budget!


Celestron Tabletop 76 **$119**

Celestron FS114S **$229**

While we're known for carrying premium optics – from Questar, TeleVue, Takahashi, and more – not all of our scopes are budget-busters. We have seven scopes priced between $119 and $249, another fourteen between $250 and $499, and twenty-one more between $500 and $999. All are surprisingly good optically. All are shown in our free catalog. Call us at (405) 364-0858 for your copy.

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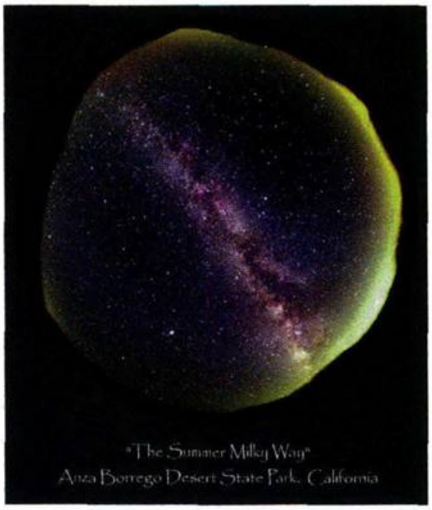
PRODUCTS



A Desert View of the Milky Way

▶ The Summer Milky Way from Anza Borrego Desert State Park in California is the subject of this beautiful 16" by 20" LightJet 5000 digital print that is suitable for the home or office. Even on cloudy nights, you'll be able to spot the Great Rift, the North America Nebula (NGC 7000), the Andromeda Galaxy (M31), and more.

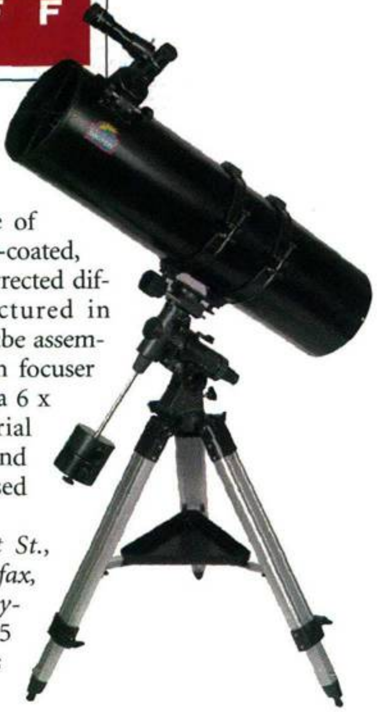
The prints are reproduced using the LightJet 5000. This state-of-the-art, large-format printer is capable of reproducing digital files with 68 million colors at a resolution of 305 dpi. Each print is signed by the photographer and printed on standard Type C photographic paper with a glossy finish.

Chris Cook, P.O. Box 52311, Irvine, CA 92619-3211; e-mail, ccjd@ix.netcom.com; website, http://www.abmedia.com/astro. The Summer Milky Way *digital print: $195*

A New Discovery

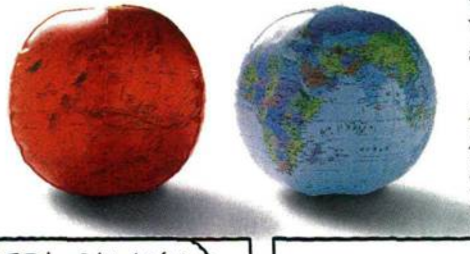
▶ Discovery Telescopes has added a new 8-inch f/5 equatorially mounted telescope to its line of Newtonian reflectors. This scope has a powder-coated, black-metal tube assembly that holds hand-corrected diffraction limited optics that are manufactured in Discovery's own optical facility. Fixed to this tube assembly are a smooth metal 1.25" rack and pinion focuser with a built-in T-thread for your camera and a 6 x 30mm finderscope. The telescope's equatorial mount rests atop an adjustable height tripod and features a polar alignment scope and enclosed worm gears. Two Plössl eyepieces are included.

Discovery Telescopes, 615 South Tremont St., Oceanside, CA 92054; phone, (760) 967-6598; fax, (760) 967-6798; website, http://www.discovery-telescopes.com. Discovery 8-inch f/5 Equatorially Mounted Reflector: *$599 plus shipping and handling.*



Play Ball

▶ Have a ball while learning more about the planet Mars with On The Wall Productions' new inflatable Mars Ball. Developed with help from the Jet Propulsion Laboratory and the California Institute of Technology, the Mars Ball uses NASA mapping imagery to accurately reproduce the planet's surface. Look for the volcanoes of the Tharsis Plateau including the largest volcano in the solar system, Olympus Mons. Other geographic features include Valles Marineris, Syrtis Major, the Elysium plains, and more. Also marked are the Pathfinder and two Viking landing sites.

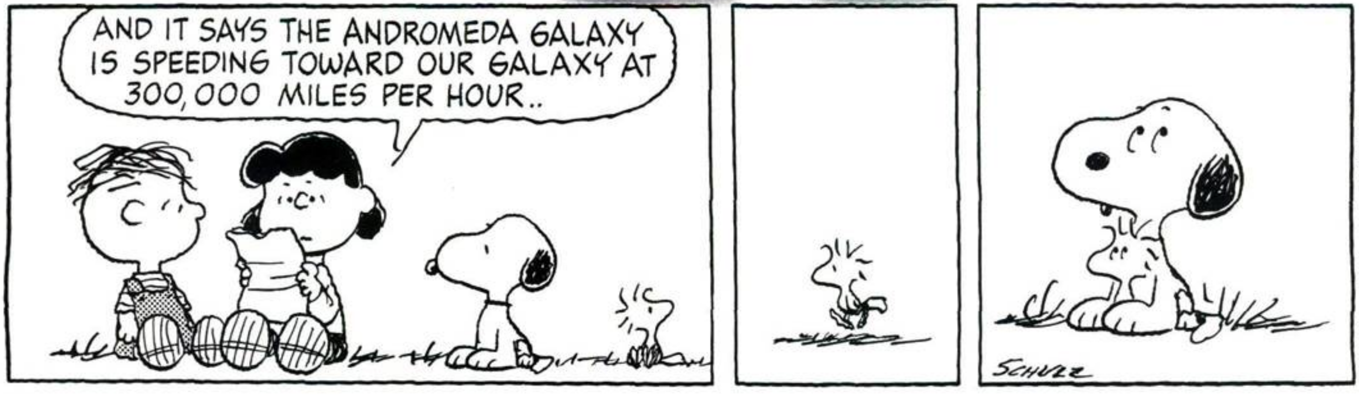


The 15" vinyl ball is a useful teaching tool. It can be hung in a classroom, child's room, or tossed around in the pool. It can also be used to track upcoming NASA missions to Mars.

On the Wall Productions, 8312 Olive Blvd., St. Louis, MO 63123; phone, (800) 788-4044; fax, (314) 213-3194; e-mail, screamkim@fclass.net; website, http://www.screameria.com. Inflatable Mars Ball: *$10*

The Earth Ball features contemporary cartography that is easy to read. Each country is shown in a separate color while country names are labeled in red and major cities and states are in black.

Hubbard Scientific, P.O. Box 2121, Fort Collins, CO 80522; phone, (800) 289-9299; fax, (970) 484-1198; website, http://www.amep.com. Inflatable Earth Ball: *$7.95 (20" pictured), $11.25 (27").*


AND IT SAYS THE ANDROMEDA GALAXY IS SPEEDING TOWARD OUR GALAXY AT 300,000 MILES PER HOUR..
SCHULZ

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Finding Stars

▶ Looking for a unique planisphere? Learning Technologies offers two intriguing candidates: the *Precession of the Equinoxes Historical Planisphere* and *Heifetz Planisphere.*

Like other planispheres, the *Heifetz Planisphere* demonstrates which stars are visible at a given latitude for a time selected by the user. Unlike most star finders, it features undistorted images of the constellations along its periphery. The constellations are as they appear in the real sky. The back of the planisphere features tips for locating constellations by means of a series of 10 triangles.

The *Precession of the Equinoxes Historical Planisphere* is based on a 30° north sky and has a 10" diameter. By illustrating precession (the wobble of Earth's axis), this planisphere is able to show the positions of stars thousands of years into the future or into the past. It demonstrates each star's change in declination and shows which star will be the North Star.

Learning Technologies, 40 Cameron Ave., Somerville, MA 02144; phone, (800) 537-8703; fax, (617) 628-8606; e-mail, starlab@starlab.com; website, http://www.starlab.com. Heifetz Planisphere: *$9.95,* Historical Planisphere: *$12.95*

PRODUCT INFO

Astronomy assumes no responsibility for the product information supplied by manufacturers. Prices are retail and subject to change without notice. Suppliers should send announcements and color photographs to Star Stuff, P.O. Box 1612, Waukesha, WI 53187, or e-mail starstuff@astronomy.com. Check *Astronomy*'s website for further product information — http://www.astronomy.com

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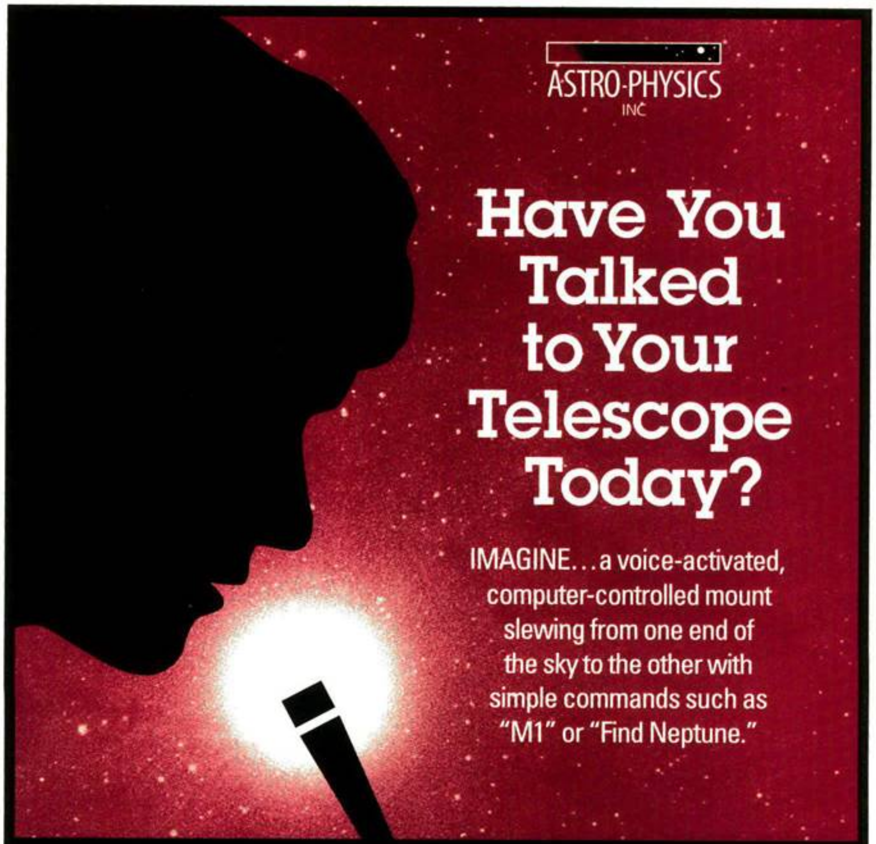

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BOOKS

The Night Sky Observer's Guide, Volume 1: Autumn & Winter
The Night Sky Observer's Guide, Volume 2: Spring & Summer

George Robert Kepple and Glen W. Sanner, 430 pages (Vol. 1), 506 pages (Vol. 2), Willmann-Bell, Richmond, Virginia, 1998; ISBN 0-943396-58-1 (Vol. 1), 0-943396-60-3 (Vol. 2); hardcover, $34.95 each.

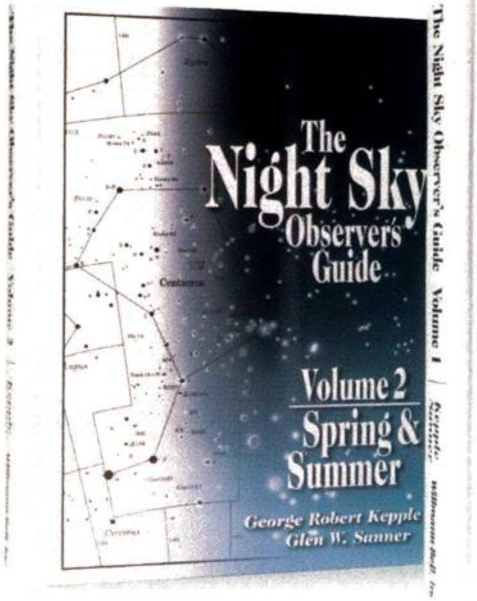
▶ Birders have their bible in the form of Roger Tory Peterson's field guide. Bird illustrations, descriptive text, and maps comprise a guide used by birders for decades. Now apply that strategy to observational astronomy and you'll have *The Night Sky Observer's Guide.*

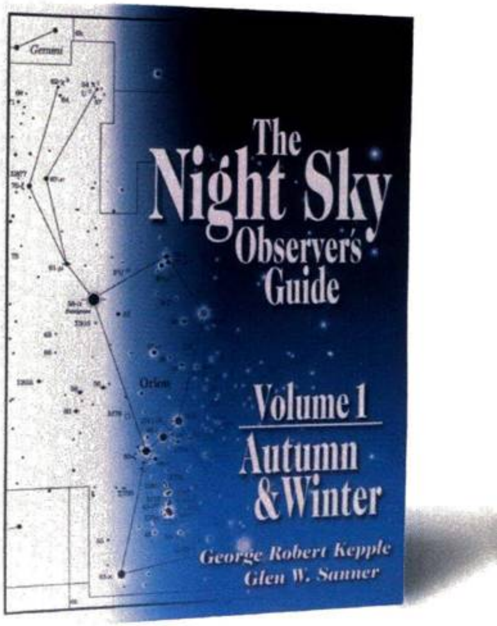
All told, the *Observer's Guide* serves up 5,541 targets: 2,104 double stars, 433 variable stars, 2,030 galaxies, 127 planetary nebulae, 131 bright nebulae, 68 dark nebulae, 550 open clusters, 93 globular clusters, and 5 miscellaneous objects such as quasars and asterisms. The two volumes span almost 1,000 pages and are divided into 64 chapters, one for each constellation visible from mid-northern latitudes.

A large constellation map, which plots stars down to 5th magnitude, anchors each chapter. Prominent stars and deep-sky objects are labeled. Detailed finder charts printed throughout each chapter show stars as they appear through an 8x50 finderscope or 7x50 binoculars. They not only reveal the location of all objects described in the text, but also describe star patterns useful in star-hopping.

The text describes what you can expect to see in a multitude of objects through a variety of telescopes, ranging in size from 4 to 18 inches. Each description includes size, brightness, and positional information, as well as a five-star system that rates an object's prominence. In all, the *Observer's Guide* incorporates 446 photos, 827 eyepiece drawings, 431 star charts, and 143 informative tables that mesh seamlessly with the descriptive text.

But lest you think it's all observe, observe, observe, Volume 1 opens with an exceptional 35-page introduction written by *Astronomy* contributor Craig Crossen. His narrative is a primer on stellar and galactic astronomy that helps you understand scientifically what you're seeing through the eyepiece. Chapter 1 follows with useful observing tips. Then, with chapter 2, it's on to the night sky, alphabetically by season through chapter 65.

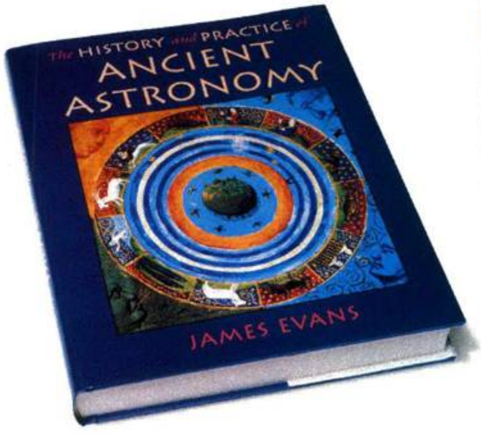




Comparisons will inevitably be drawn between the *Observer's Guide* and a deep-sky observer's perennial favorite, the 3-volume *Burnham's Celestial Handbook. Burnham's,* with its emphasis on descriptive histories and tables, is more of a reference work. On the other hand, the *Observer's Guide*'s generous use of maps, drawings, and photos places it squarely in the realm of a bona fide field guide.

Despite the overall high quality of these two volumes, I have a few minor quibbles. An end-all reference book for deep-sky objects should devote more space to what you can see in even larger telescopes. Additional space should have been carved out for some of the subtle but stunning treasures of the night sky. For example, the annotated map, photo, and descriptive text for the glorious face-on spiral galaxy M101 make no mention of isolated star-forming regions in its spiral arms — some of which are so bright they've been given their own NGC designations. Even an 8-inch scope working with the right filter under dark, transparent skies will start to show lumpy clumps of fuzzy light. (In fairness, the authors do a wonderful job on M33's star-forming regions.)

But these criticisms should not detract from what is an exemplary guide to the deep sky. To do so would be like sulking over a huge slice of apple pie topped with ice cream because it lacks an extra dollop of whipped cream. Both are still richly filling and oh-so-satisfying all the same. — *John Shibley, contributing editor*



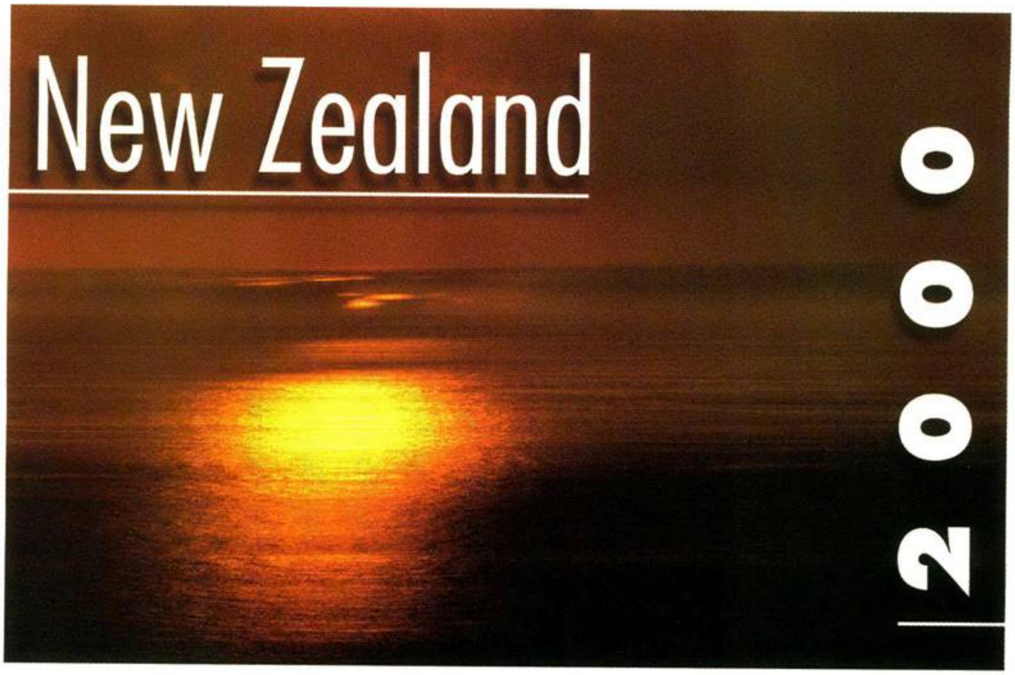
The History and Practice of Ancient Astronomy

James Evans, 480 pages, Oxford University Press, New York, 1998; ISBN 0-19-509539-1; hardcover, $65.

▶ *The History and Practice of Ancient Astronomy* combines scholarship with hands-on science. Evans not only traces astronomical ideas from ancient Babylon through to the sixteenth century, but he dots the text with exercises that offer the reader a better understanding of how these ideas came into being. The book is extensive in its coverage and offers more than your run-of-the-mill presentation of astronomical methods. If you seek an encyclopedic look at ancient astronomy, search no further.

Astronomy Magazine presents

The Millennium Tour



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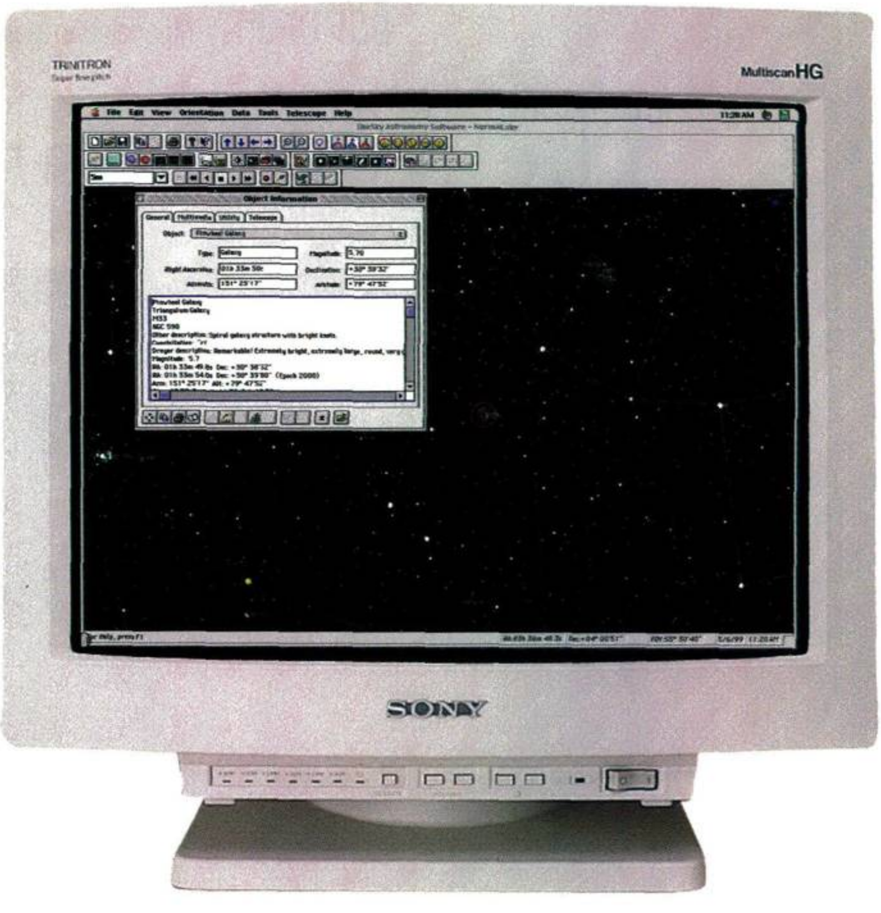

BYTES

The Sky for Macintosh

At long last Mac users can have the power and capabilities of Software Bisque's *The Sky* at their fingertips. With virtually the same features as the Windows Level III version, *The Sky for Mac* is no simple clone of its Windows cousin. *The Sky for Mac* is optomized for the Macintosh 8.5 operating system and accelerated for the Power Mac.

Features include a planetarium-like display that allows the user to view the sky from 4712 B.C. to 10,000 A.D. from any location on Earth; the ability to invert the display to simulate the sky as it might appear through a telescope; built-in controls for most commercially available telescopes; a bull's-eye overlay that indicates the field of view through an eyepiece, Telrad, CCD camera, etc; and much more.

By far the most impressive aspect to *The Sky* is its ability to call upon and cross-reference vast databases. All the big names are here. *The Hubble Guide Star Catalog* alone is cross-referenced with the *Smithsonian Astrophyiscal Observatory Catalog*, the *Positions and Proper Motion Catalog*, the *Henry Draper Catalog*, and others. Click on a star and a window pops up with data from the *Hipparcos-Tycho Catalogs.* Its spectral class, proper motion, magnitude, parallax, distance, right ascension, declination, altitude, azimuth, rise, set, and transit times are all displayed. *The Sky* even calculates the angular separation and position angle between two objects, a handy tool indeed. If the vast amount of data incorporated into *The Sky* still isn't enough, then add your own customized data from a text file.

System Requirements: any Power Macintosh (including the iMac), Mac OS 7.6 or later (Mac OS 8.5 or later recommended), a display capable of 256 colors or more, CD-ROM drive, 16 MB of free RAM, 40 megabytes (minimum) of free disk space.

Software Bisque, 912 Twelfth Street, Golden, Colorado 80401-1114; phone, (800) 843-7599; fax, (303) 278-0045; e-mail, thomasb@bisque.com; website, http://www.bisque.com. The Sky for Macintosh: *$129* ■

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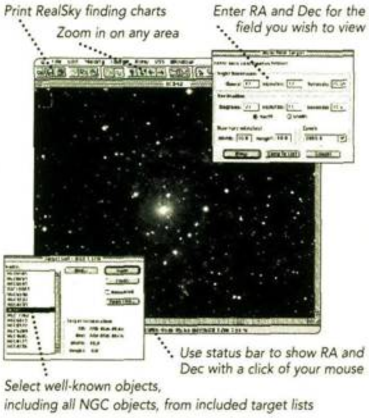
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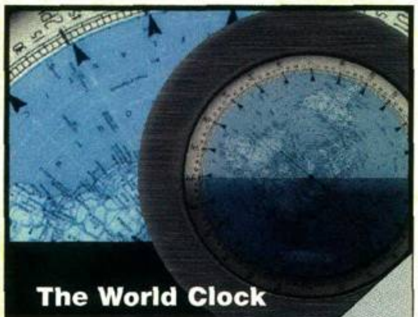

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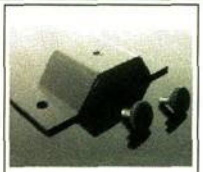

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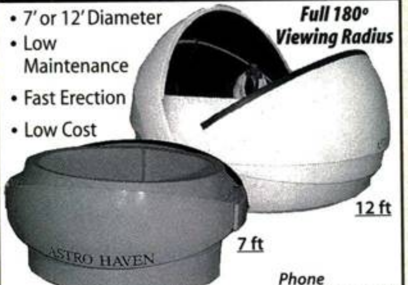

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The Big Dipper overlooks a sunflower-covered hill.

Douglas C. Zubenel

Montana's Big Sky Country comes alive at The Big Mountain Ski and Summer Resort's **Stargazer Evenings** scheduled for **July 2nd and 16th, August 20–21st Overnight Party,** and **September 3rd Kids' Night.** Local amateur astronomer, Steve Bryson, will bring several high-powered telescopes to the summit for an informative, fun evening the entire family will enjoy. For more information, contact Syd Ryerson, The Big Mountain Ski and Summer Resort, P. O. Box 1400, Whitefish, MT 59937; (406) 862-2900; website, http://www.bigmtn.com.

Correction

The **Rocky Mountain Star Stare** will be held in the Pike National Forest, Colorado, **July 8–11.** For more information, call the CSAS event line, (719) 596-3672; website, http://members.aol.com/bygrens/CSAS.html.

AUGUST 1–22

International Astronomical Youth Camp

▶ Town of Vep, near Szombathely, Hungary. Contact the International Workshop for Astronomy e. V., c/o Gwendolyn Meeus, Parkstraat 91, 3000 Leuven, Belgium; e-mail, info@iayc.org; website, http://www. iayc.org/.

AUGUST 5–11

European Symposium on Occultation Projects

▶ Stuttgart, Germany. Contact Otto Farago at the Swabian Observatory, Seestrasse 59/A, D-70174 Stuttgart, Germany; telephone, 49-711-226-0893; e-mail, farago@t-online.de; website, http://www.sternwarte.de/esop-99.

AUGUST 6–8

Syracuse Summer Seminar

▶ Darling Hill Observatory, south of Syracuse, New York. Contact Karl Schultz, 25 South Street, Apt. C82, Marcellus, NY 13108; (315) 673-3556; website, http://www.syracuse-astro.org.

AUGUST 6–15

Summer Star Party

▶ Shady Pines Campground, Savoy, Massachusetts. Contact Don Urban, 73 Haring Street, Closter, NJ 07624-1709; (201) 768-3295; e-mail, DonaldUrban@Juno.com.

AUGUST 7–14

Nebraska Star Party

▶ Merritt Reservoir, near Valentine, Nebraska. Contact Tom Miller, 3400 N. 102nd Street, Lincoln, NE 68527; (402) 466-4170; e-mail, tmiller232@aol.com; website, http://www.4w.com/nsp/.

AUGUST 7–15

Mt. Kobau Star Party

▶ Okanagan Valley, British Columbia, Canada. Contact Jim Failes, e-mail, eij@bcinternet.com or MKSP Registrar, P. O. Box 20119 TCM, Kelowna, BC V1Y 9H2; website, http://www.bcinternet.com/~mksp.

AUGUST 10–15

Astroblast

▶ Oil Region Astronomical Observatory, Two Mile Run County Park, Franklin, Pennsylvania. Contact ORAS, P. O. Box 351, Reno, PA 16343 or John O'Hara, (814) 677-3972.

AUGUST 10–15

Great Manitou Star Party

▶ Gordon's Park and Carter Bay, Manitoulin Island, northern Lake Huron, Ontario, Canada. Contact Mark Oldfield, 1687 Carol Street, Val Caron, ON P3N 1H1; (705) 897-4518; e-mail, moldfiel@ctv.ca or greatmanitou@hotmail.com.

AUGUST 12

Free Public Star Party

▶ Ralph A. Worley Observatory, south of Shreveport, Louisiana. Contact Cran Lucas, (318) 797-1524; website, http://www. lsus.edu/nonprofit/sbas/.

AUGUST 12

Hurricane Ridge Star Party

▶ Olympic National Park, Port Angeles, Washington. Contact John Gallagher at (360) 452-0260; e-mail, jgalla@pasd. wednet.edu.

AUGUST 12–14

Table Mountain Star Party

▶ Lion Rock, Table Mountain, northwest of Ellensburg, Washington. Contact TMSP, Marcie Roundtree, P. O. Box 785, Puyallup, WA 98371; Kerry Winston, (253) 846-4786; e-mail, winstkj@gte.net.

AUGUST 12–14

Weekend Under the Stars

▶ Foxpark, Wyoming. Contact the Cheyenne Astronomical Society, 3539 Luther Pl., Cheyenne, WY 82001; Marty Curran, (307) 635-5944; website, http://users.sisna.com/mcurran/wuts.htm.

AUGUST 12–15

Idaho Star Party

▶ Bruneau Dunes State Park, Bruneau,

Idaho. Contact Mike Blackburn, (208) 375-8850.

AUGUST 13–14
Montana Starwatch

▶ Ruby Reservoir, near Virginia City, Montana. Contact Mike Murray, Museum of the Rockies, 600 W. Kagy Boulevard, Bozeman, MT 59717; (406) 994-6891; website, http://www.montana.edu/smas web.

AUGUST 13–14
Stellafane Convention

▶ Breezy Hill, Springfield, Vermont. For more information, send a SASE to Stellafane Convention, P. O. Box 50, Belmont, MA 02178; website, http://www.stellafane.com.

AUGUST 13–15
Astro Atlantik Star Party

▶ Camping Shippagan Campground, New Brunswick, Canada. Contact Jacques Robichaud, (506) 336-8085; website, http://www.osco.nb.ca/nbanb.

AUGUST 13–15
Huronia Star Party

▶ Kueper farm, near Lisle, Ontario, Canada. Contact Christopher Trace, P. O. Box 719, Beeton, Ont. L0G 1A0; (905) 729-4982.

AUGUST 13–15
Northwoods Starfest

▶ Hobb's Observatory, Fall Creek, Wisconsin. Contact Ray Forsgren, Hobb's Observatory, County Road K, Fall Creek, WI 54742; (715) 877-2212; website, http://www.cvastro.org.

AUGUST 13–15
Saskatchewan Summer Star Party

▶ Cypress Four Seasons Resort, Cypress Hills Interprovincial Park, Saskatchewan, Canada. Contact SSSP '99, Saskatoon Centre, RASC, P. O. Box 317, RPO University, Saskatoon, SK S7N 4J8; Les and Ellen Dickson, (306) 249-1091; website, http://maya.usask.ca/~rasc/rasc.html.

CONTACT

Please submit club announcements four months in advance to Looking Ahead, *Astronomy*, P.O. Box 1612, Waukesha, WI 53187-1612, or to tconley@astronomy.com. Look for additional events at http://www.astronomy.com.

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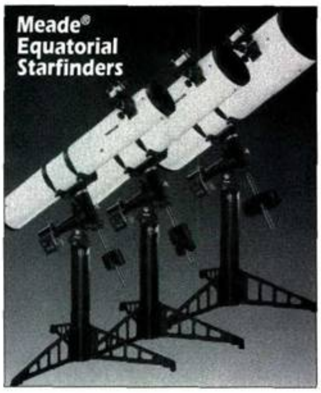

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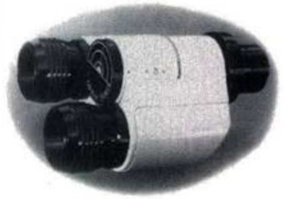

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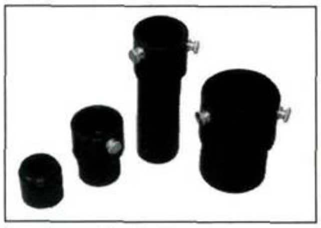

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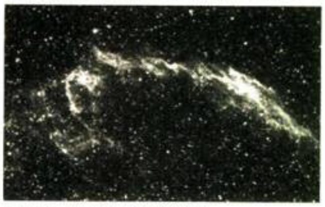

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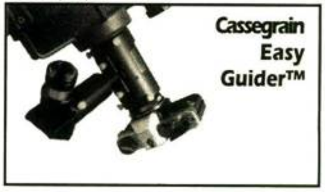

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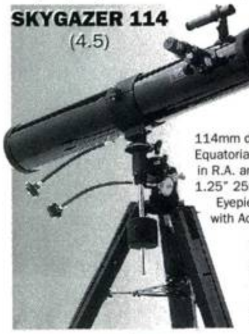

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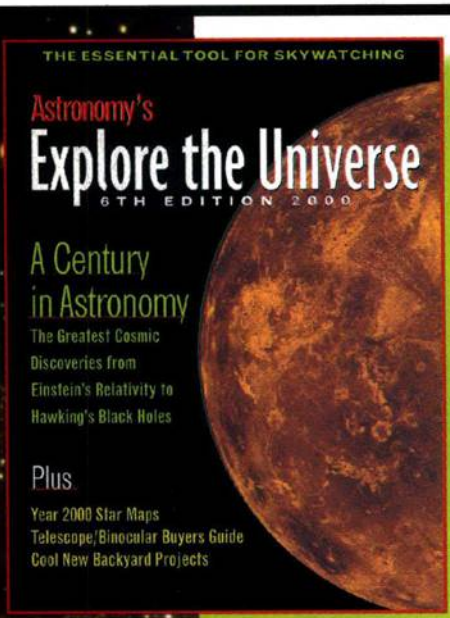
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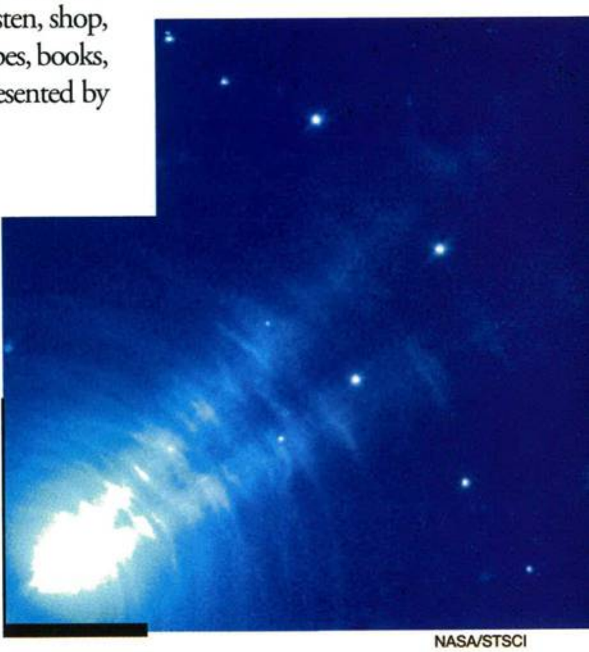

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NEXT month in Astronomy

Kim Zussman

IN THE BEGINNING

The Big Bang may have given birth to our universe and everything in it, but many cosmologists are probing deeper, asking what started the Big Bang.

ARCHITECTS OF TIME

One of humanity's first forays into measuring time, Stonehenge laid a foundation for turning the motion of Earth into the precise clocks of today.

INTO A WATERY REALM

The constellations of Pisces and Cetus offer backyard observers plenty of galaxies (above), as well as a wonderful variable star.

YOU SAY TOMATO

Quick — name that bright red star in Orion. If you said Beetlejuice instead of Betelgeuse, our handy pronunciation guide will fix you up in no time.

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BELOW THE BELT

O Beautiful for Southern Skies

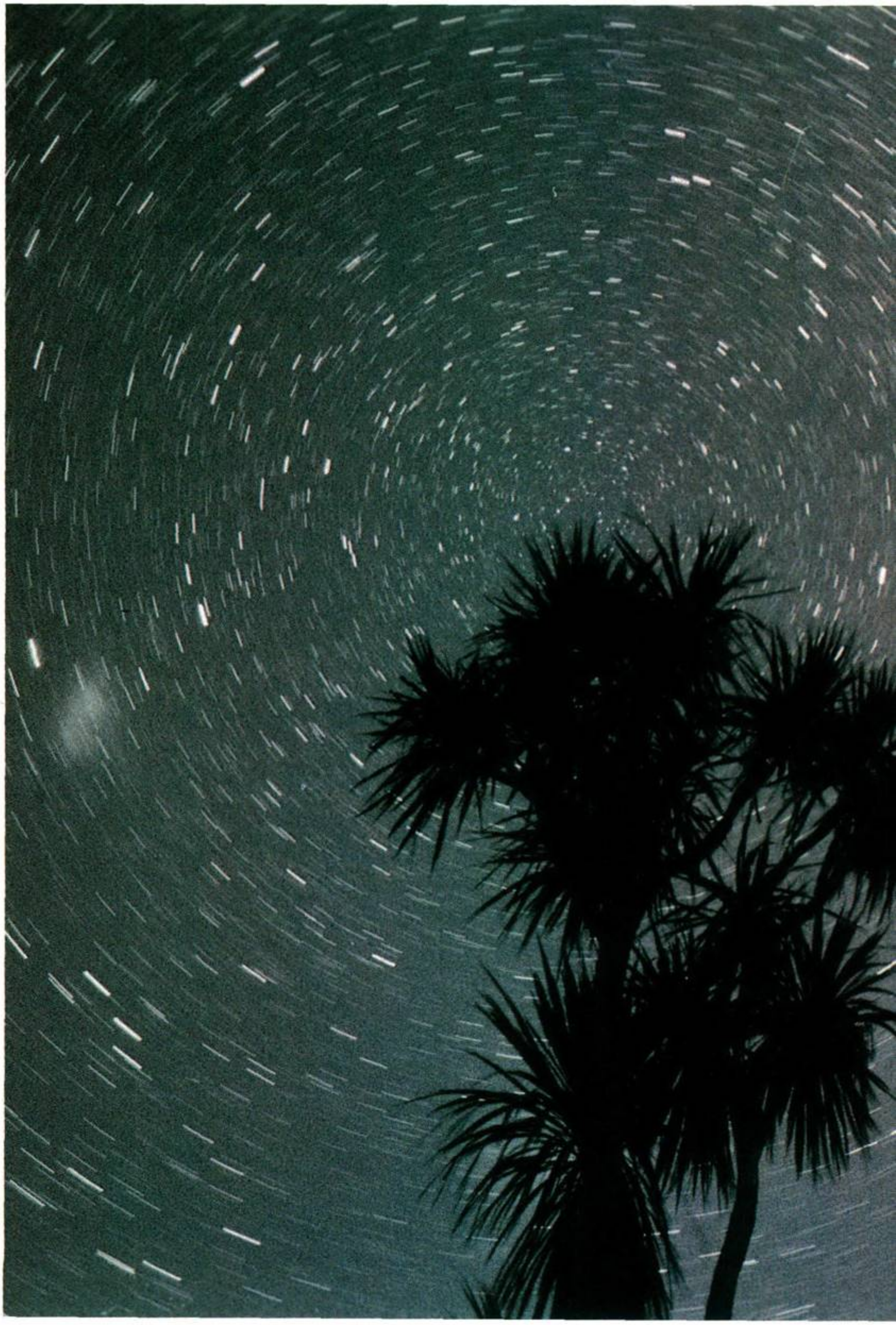
It has often been said that astronomers in the Southern Hemisphere have better skies than their counterparts up north. As somebody who has spent half his life in the north and half in the south, I feel qualified in comparing the two hemispheres.

My location is 45° south of the equator, on a farm some ten miles from the small town of Oamaru on New Zealand's South Island. The skies here are gin clear, especially in the early mornings a couple hours before sunrise.

As far as the moon and planets are concerned, there is very little difference between hemispheres. Observations of deep-sky objects in the constellations of the middle heavens are also the same. It is not until we compare the polar regions that a definite difference is apparent.

For starters, there are the two large naked-eye galaxies known as the Magellanic Clouds, which look like detached parts of the Milky Way. They are so obvious that they can even be seen from the centers of towns. In 1987, southern observers were treated to the first naked-eye supernova in four hundred years, in the larger of the two clouds.

Two bright globular clusters grace the polar region, Omega Centauri and 47 Tucanae. They are both amazing sights, even through small telescopes. Two other interesting



The Small Magellanic Cloud and the Coal Sack

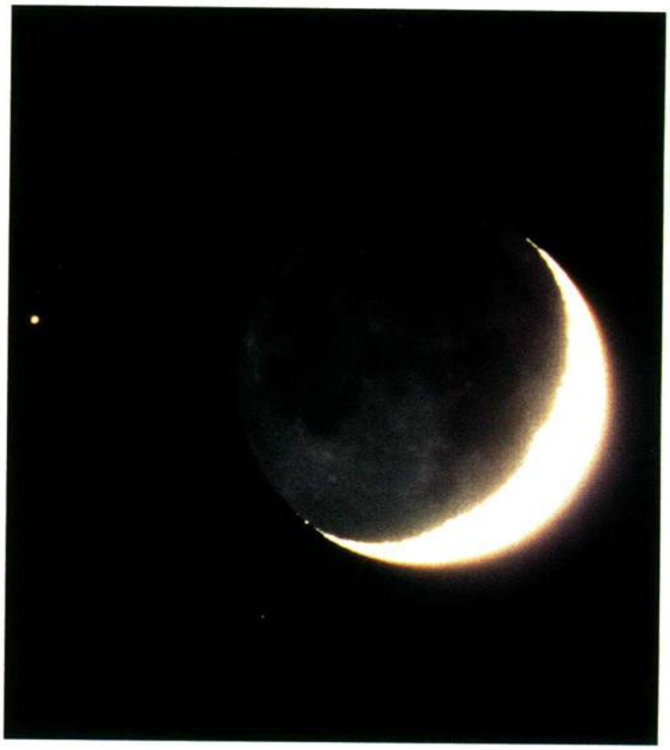
DAVID ARMSTRONG

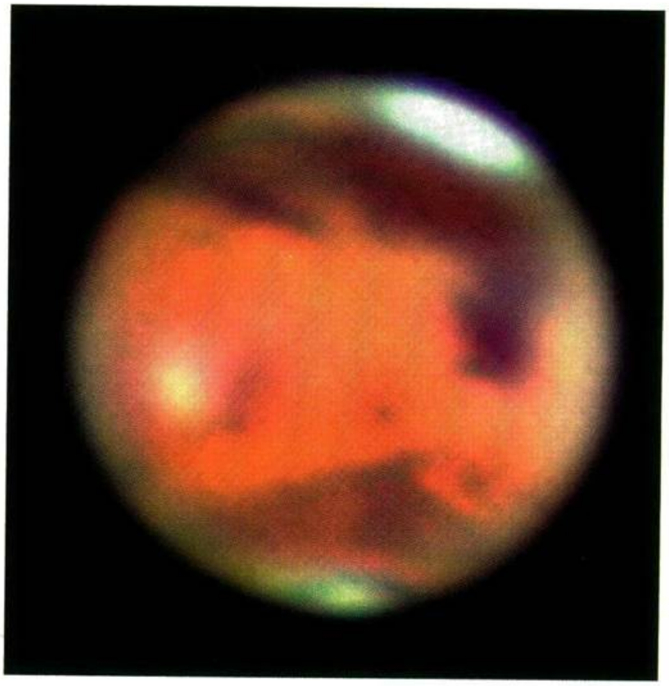
(12-minute exposure)

Aldebaran Meets the Moon

JARED WRIGHT

(1000mm lens at f/6.3, ISO 400 film, 4-second exposure taken April 18, 1999)





The Many Colors of Mars DON PARKER

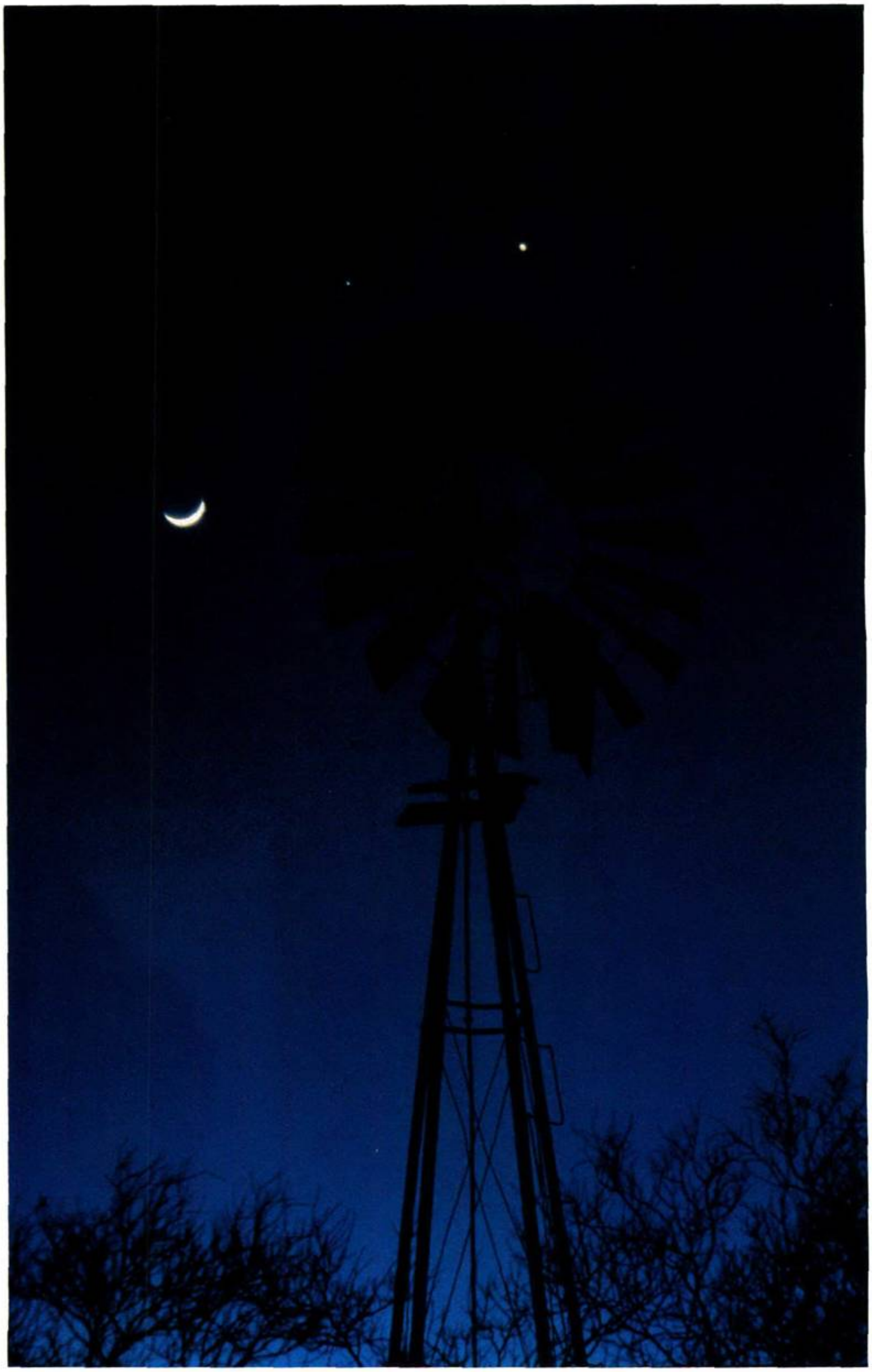
(16-inch reflector at f/48, Lynxx CCD camera, composite of 14-second blue, 6-second green, and ½-second red exposures taken April 17, 1999) objects that are close together in the south polar sky are Eta Carinae and the great open cluster NGC 3532, said to be the finest cluster in the entire sky. Eta Carinae is a strange, variable star immersed in the Keyhole Nebula and is a candidate for the "supernova club."

The best known and smallest constellation in the southern sky is Crux the Southern Cross. Within the Cross is the A-shaped open cluster known as the Jewel Box (NGC 4755), a vivid collection of blue-white supergiants with a red supergiant in the center, looking like a ruby among a sea of diamonds. Also within the Cross is the Coal Sack, a dark fog best seen using averted vision.

Two bright stars point to the Southern Cross, Alpha and Beta Centauri, our nearest stellar neighbors. Through a telescope they look like a pair of headlights. This double star never fails to intrigue people when they see it for the first time.

So, are the southern skies better than those up north? Was it Sir John Herschel who said that northern astronomers were living in the wrong hemisphere? I think he may have been right. As far as the polar region is concerned, northern observers have drawn the short straw. With very little light pollution and a high percentage of clear skies, this vantage point on the planet is an astronomer's dream. ■

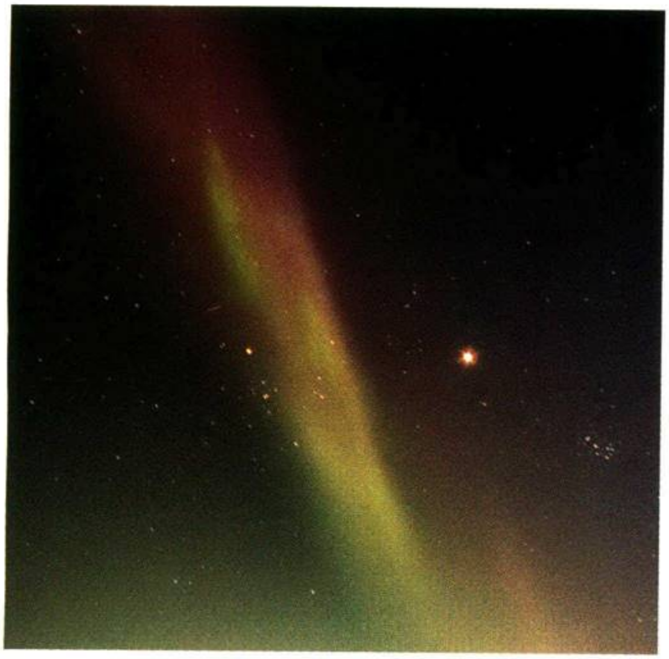
David Armstrong and his wife fashion their own telescope accessories while waiting to see the aurora australis. They had a "lousy view" of Hale-Bopp.



Moon, Saturn, and Venus Frame a Windmill

DAVID LINNIG

(180mm lens at f/16, Fujichrome Velvia film, 10-second exposure taken March 19,1999)



Auroral Patch Shimmers beside Venus and the Pleiades

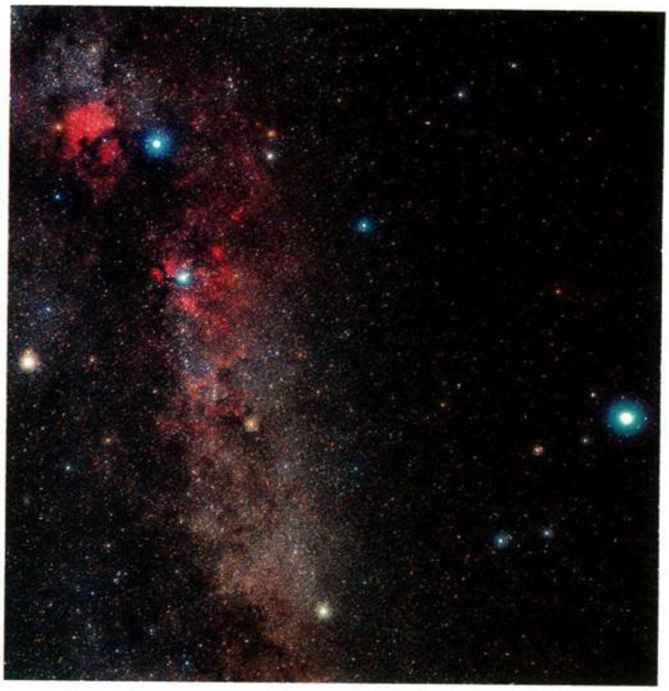
GARY BAIER

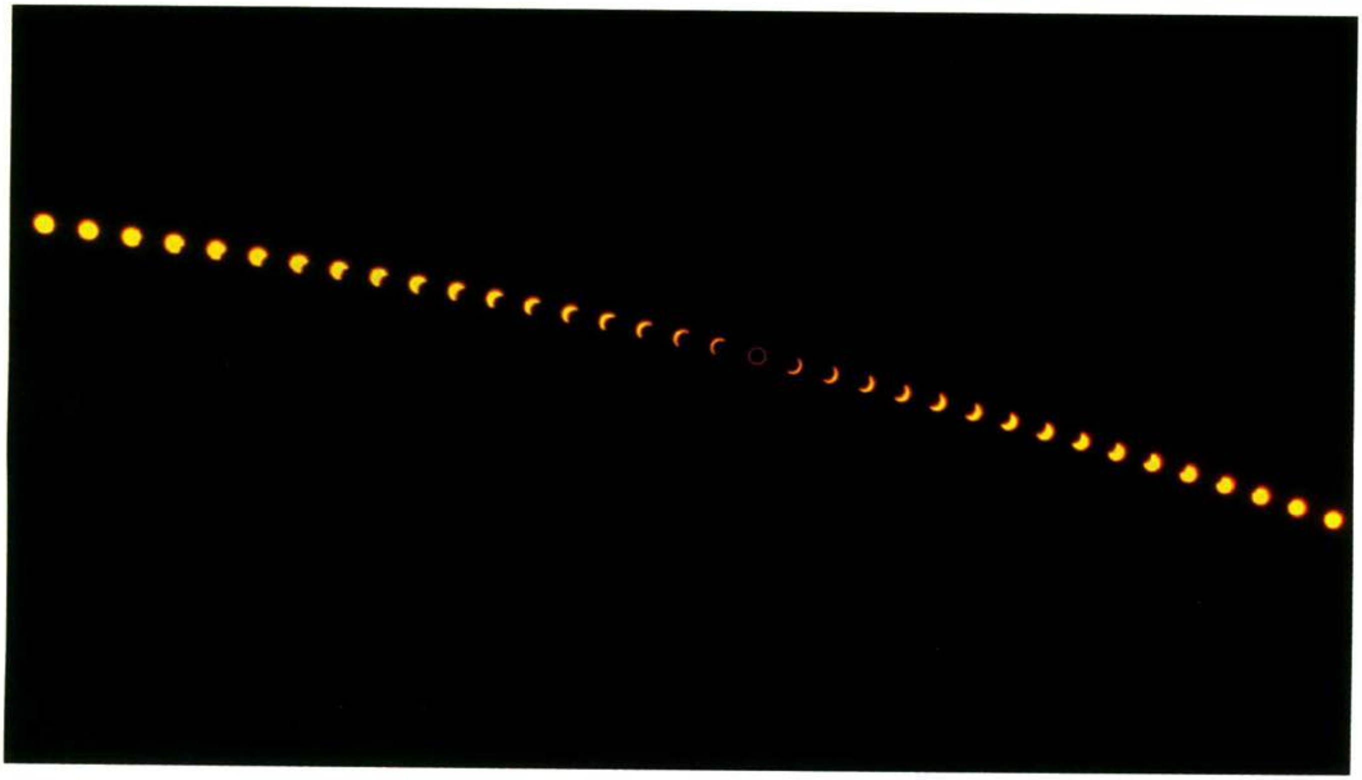
(50mm lens at f/3, Kodak Gold 800 film, 30-second exposure taken April 16, 1999)

Cygnus and Lyra Reveal Their Secrets

BILL AND SALLY FLETCHER

(90mm lens, Kodak Pro 400 PPF film, 60-minute exposure)



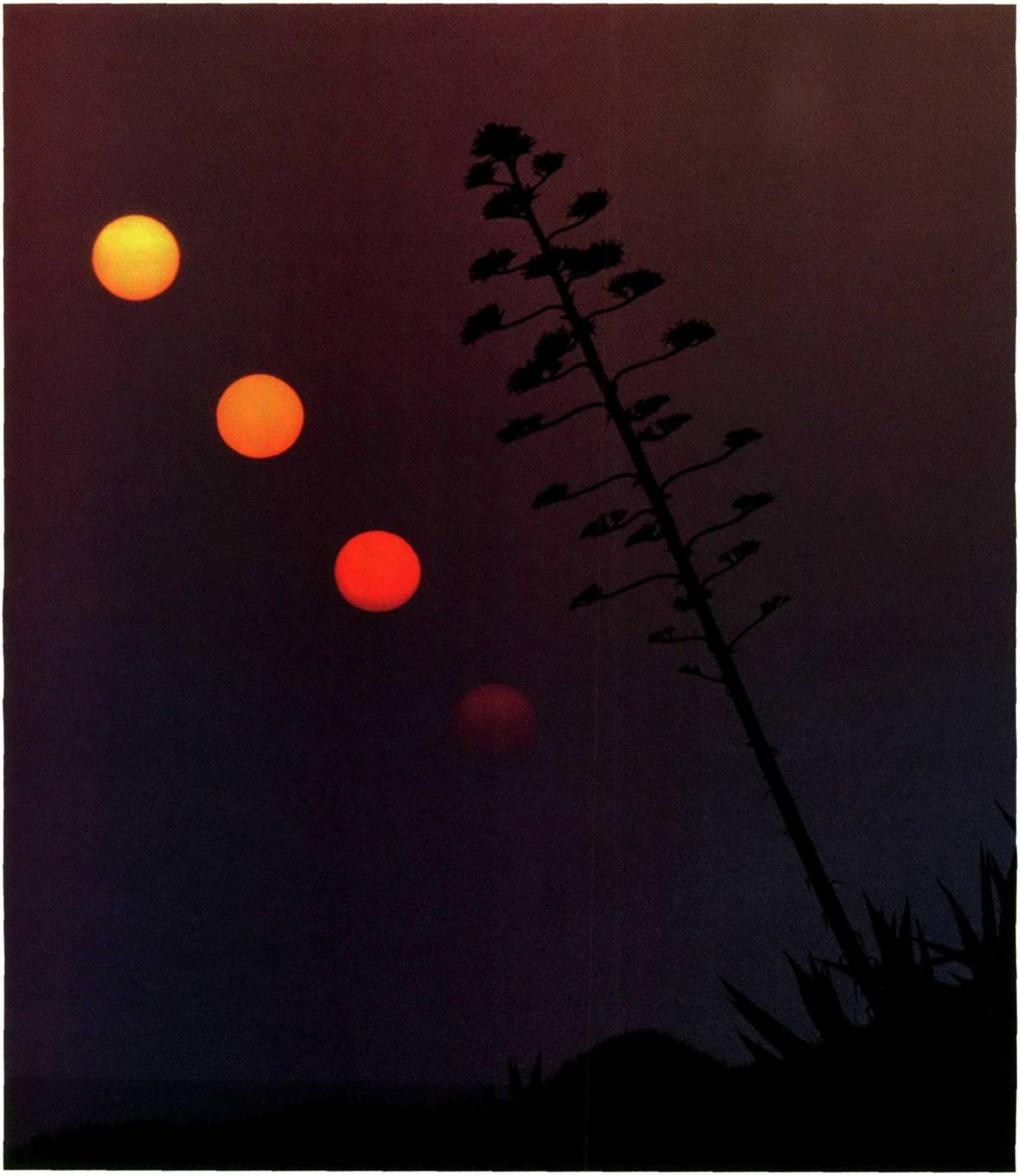


Stages of an Annular Eclipse **GENEVIÈVE DELAYE**

(50mm lens, partial eclipse at f/16, total eclipse at f/11.5, Kodak Ektachrome 100 film, $\frac{1}{125}$-second each exposure, 5 minutes between exposures taken February 16, 1999)

ULTIMATE EXPOSURE

This month's best astrophoto



Sicilian Sunset

GIANNI TUMINO

(180mm lens at f/32, Fuji Velvia 50 ISO film, series of 1/4000-second exposures every 5 minutes,.10-second final exposure taken 30 minutes after sunset, April 6, 1999)

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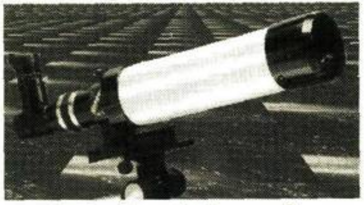

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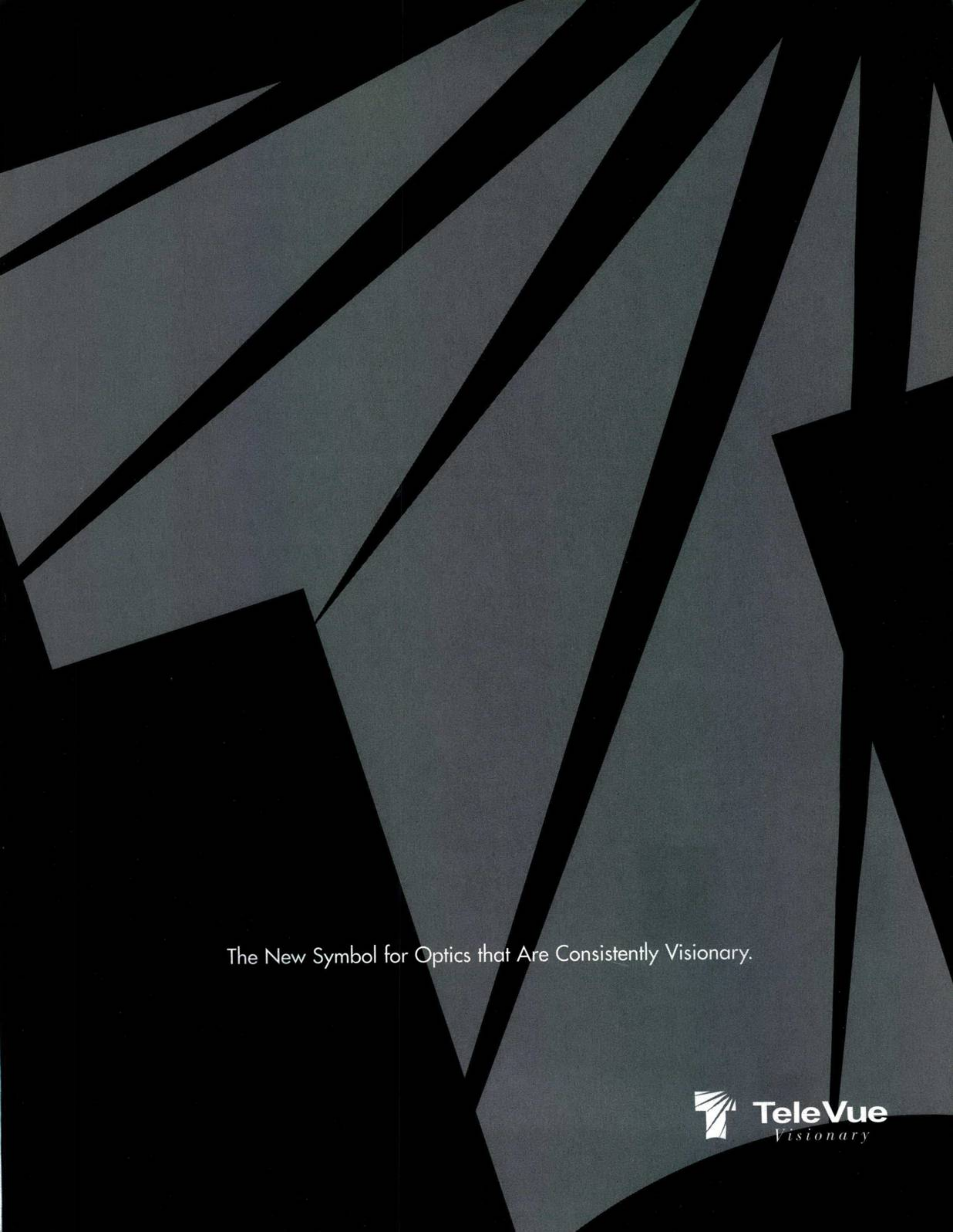
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